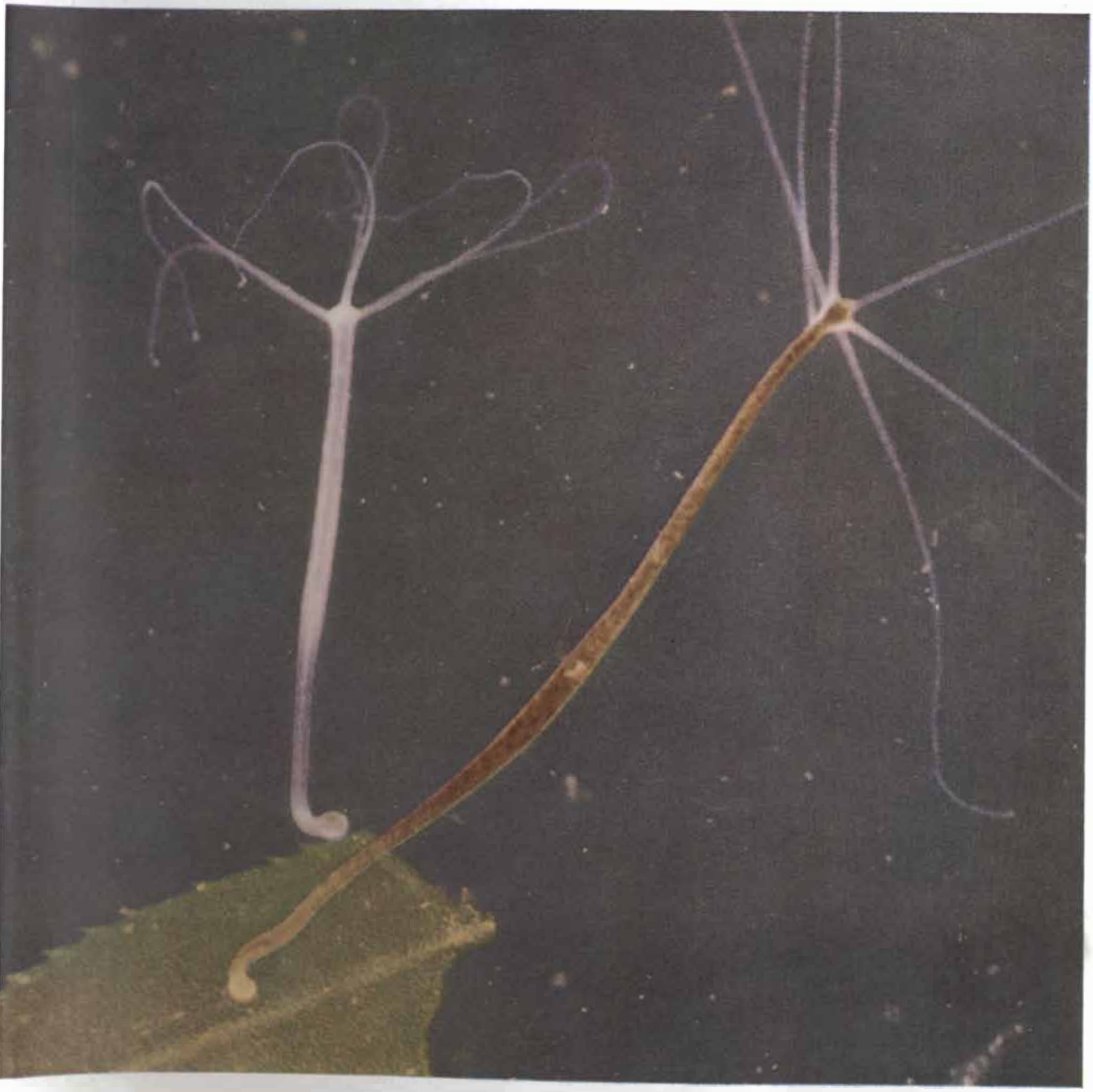
SCIENTIFIC AMERICAN



HYDRA

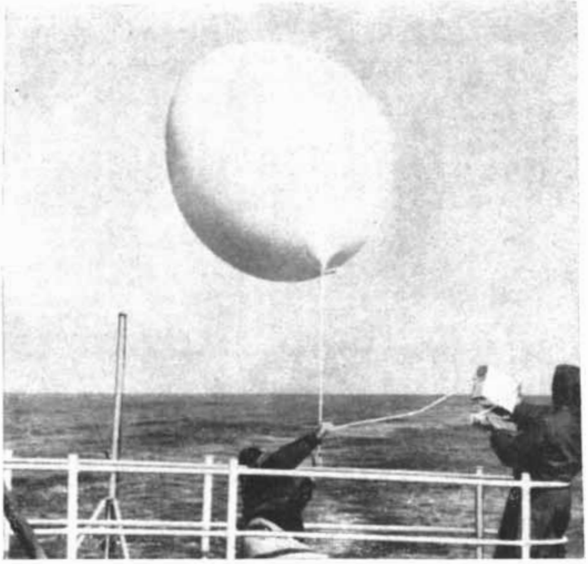
FIFTY CENTS

December 1957


Sensitive
Princess
Spends
Sleepless
Night
SHELL

Aluminum Inflates I. G. Y. Weather Balloons

...and versatile aluminum powders offer wide-ranging properties for many applications



Reynolds Aluminum granular powder helps generate hydrogen for this I.G.Y. weather balloon. Photo courtesy Dewey & Almy Chemical Co., Div. of W. R. Grace & Co.

The news that aluminum powders are being used to generate hydrogen for I.G.Y. weather balloons dramatizes a fact that may not be too well known: Reynolds Aluminum in powder or granular form can be as versatile—and as effective—in many chemical and manufacturing processes as is solid aluminum.

For example, the Reynolds Aluminum granular powder, HPS-9, which is reacted with a caustic solution to generate hydrogen: It actually gives weathermen a simple, portable generating plant, to provide savings in storage tanks and equipment. Together with a close relative, HPS-10, it is equally efficient and effective in many other uses including:

- **reducing agents in preparation of alum**
- **ingredient in metal plastics**
- **fuel**
- **in "Hot Tops" (Exothermic Reactions)**
- **in preparation of metals from ores, oxides, and/or solutions**
- **as a sacrificial metal in chemical reaction**

REYNOLDS GRANULAR POWDER CHARACTERISTICS

Reynolds HPS-9 and HPS-10 are 99.3 plus percent pure aluminum in granular form. In chemical reactions they are more efficient than atomized aluminum powder with the same screen analysis, and they have a lower apparent density.

REYNOLDS NEW GRANULAR ALUMINUM POWDERS

A new form of granular aluminum, in the same group as HPS-9 and HPS-10, are 200x and 300x powders, recently developed by Reynolds. These 99.3 plus percent pure aluminum powders offer reaction rates and flow properties not previously found in this form. They are meant for use in the production of aluminum chemicals, catalysts, fuels, etc.

Typical Properties of Reynolds Granular Aluminum Powders

GRADE	RETENTION mesh screen	RETENTION percent average	APPARENT DENSITY grams per cc—average
HPS-9	10 60	12.0 95.0	0.60
HPS-10	12 140	0.5 97.0	0.65
200x	10 60	1.0 99.5	1.00
300x	6 40	1.0 99.0	1.10

REYNOLDS ATOMIZED ALUMINUM POWDERS

Reynolds also offers a wide range of atomized powders made from high purity aluminum. Atomized powders are used as reducing agents in the winning of metal from its oxides. They are also used in new catalytically polymerized epoxy resins, in protective coatings, in plastic molds, in cold solder, in abrasives, in grouting cement, and in the manufacture of alum and titanium dioxide.

Typical Properties of Reynolds Atomized Aluminum Powders

GRADE	RETENTION ON NO. 325 (44 MICRON) SCREEN percent average	APPARENT DENSITY grams per cc	PARTICLE SIZE Microns
1-701	65	1.20 ± 0.15	32 ± 5
40	40	1.20 ± 0.10	30 ± 5
120	20	1.00 ± 0.10	20 ± 5
200	10	1.00 ± 0.10	15 ± 5
1-511	5	1.00 ± 0.10	13 ± 3

TECHNICAL ASSISTANCE AVAILABLE

The aluminum powders described above are just a few of those in Reynolds complete line. Reynolds can supply aluminum in granular, flake, powder, and paste forms, with a wide range of controlled particle sizes and apparent densities, and in various purities.

If the above applications and product information suggest possible aluminum powder or paste uses for you, Reynolds chemists and engineers will be glad to work with you on research and development. Write direct to *Reynolds Metals Company, P.O. Box 1800-PS, Louisville 1, Kentucky.*

The Finest Products Made with Aluminum are made with REYNOLDS ALUMINUM

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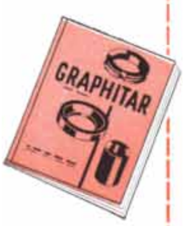
Watch Reynolds All-Family Television Program "DISNEYLAND", ABC-TV.

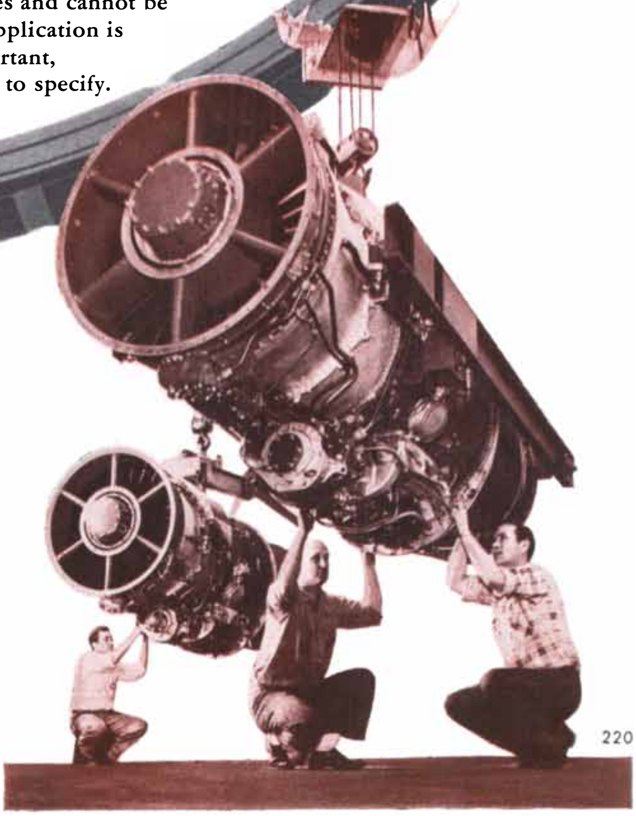
GRAPHITAR® is the main shaft seal in the PRATT & WHITNEY J57 turbojet engine

(CARBON-GRAPHITE)

● Boeing's B-52 Intercontinental Bomber, the striking arm of our Strategic Air Command, is powered by eight twin-spool axial-flow turbojet engines manufactured by the Pratt & Whitney Aircraft Division of United Aircraft Corporation, East Hartford, Connecticut. These turbojets are in the 10,000 pound thrust class and in engines of this caliber, complete dependability is vital. One of the components of the J57 is a GRAPHITAR air/oil seal employed on the turbine main shaft which, naturally, is turning at high speeds. The GRAPHITAR seal also easily withstands the maximum operating pressures developed in the engine. The slots in the face of the seal (shown approximately ⅔ size) are for pressure balance and cooling. This Main Shaft Seal is just one of several GRAPHITAR seals used in the J57 engine. GRAPHITAR parts can resist such taxing physical conditions because they are strong, self-lubricating, and practically inert. GRAPHITAR has excellent wearing properties and cannot be corroded by most chemicals. Where the application is tough, and complete dependability important, GRAPHITAR is the engineering material to specify.



From the Pratt & Whitney Turbojet Engine to the atomic submarine Nautilus, from automobile pumps to automatic toasters, GRAPHITAR is aiding the performance of literally hundreds of highly diverse products. It can be formed in relatively complicated shapes and ground to tolerances as close as .0005″ for seals, bearings, vanes, piston liners, and many other parts. For complete facts write for our new GRAPHITAR Engineering Bulletin No. 20.



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THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION • SAGINAW 6, MICHIGAN

Established 1845 **SCIENTIFIC AMERICAN** December, 1957 Volume 197 Number 6

ARTICLES

DEPARTMENTS

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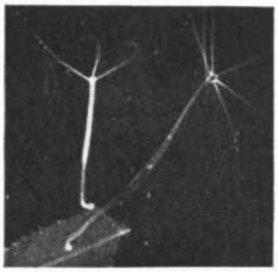

THE COVER

The color photomicrograph on the cover shows two living specimens of hydra, the tiny fresh-water organism which can grow from a small piece of another hydra (*page 118*).

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Cover photograph by Roman Vishniac

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MINIATURIZATION AWARD

THE AWARD

Miniature Precision Bearings, Inc. cordially invites you to participate in the Annual Miniaturization Award Competition. The Miniaturization Award for 1957 will be presented on March 23, 1958 at the 1st Annual Awards Dinner in New York. The Award will consist of a piece of original sculpture, symbolizing miniaturization, by a leading American artist, which is cast in bronze and inscribed. There will also be Honorable Mentions for additional outstanding contributions.

PURPOSE OF THE AWARD

To increase public knowledge of the importance of miniaturization and to stimulate further activity within industry toward the advancement of the concept of miniaturization.

CRITERIA FOR AWARD

Contributions considered for the Award should have been made in the recent past to be eligible for consideration by the Miniaturization Awards Committee. Details of criteria on which awards will be based can be obtained by writing: Awards Committee, Miniature Precision Bearings, Inc., Precision Park, Keene, N. H.

JUDGING OF ENTRIES

The awards will be judged by an eight-man independent committee comprised of the following individuals: R. L. Goetzenberger, *Educational Consultant, Minneapolis-Honeywell Regulator Co.* / Dr. George H. Lee, *Director of Research, Rensselaer Polytechnic Institute* / Morton Pavane, *Electronics Engineer, Air Research and Development Command* / Gerard Piel, *Publisher*, SCIENTIFIC AMERICAN / Gustave Shapiro, *Chief, Engineering Electronics Section, Electricity and Electronics Division, National Bureau of Standards* / George F. Sullivan, *Editor*, THE IRON AGE / Elmer Tangerman, *Editor*, PRODUCT ENGINEERING / Arthur W. Weber, *Vice President, Engineering & Manufacturing, Corning Glass Works* / Horace D. Gilbert, *President, Miniature Precision Bearings, Inc.*

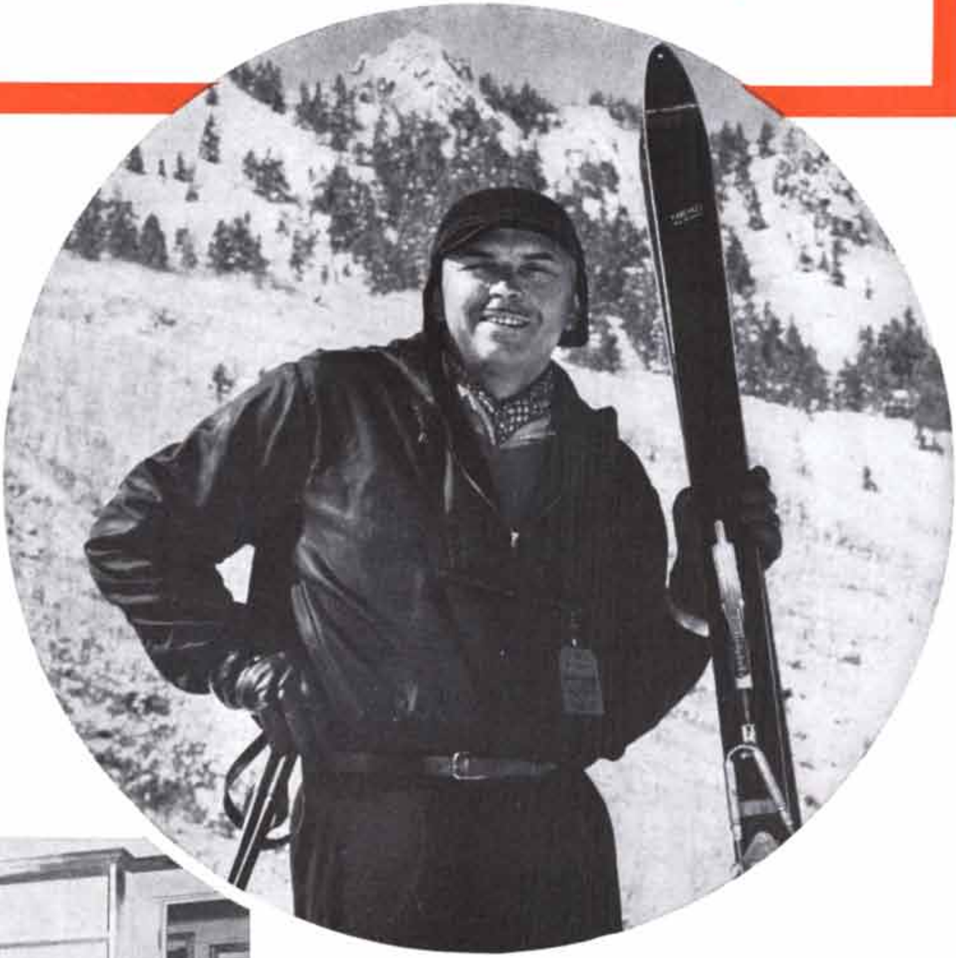
ENTRIES

Description of a specific contribution should be made in as complete a form as possible and mailed to the Awards Committee, Miniature Precision Bearings, Inc., Precision Park, Keene, New Hampshire. Samples of the product itself, blueprints or photographs will be helpful. Descriptive information should include some of the design characteristics of the product and the specific problem solved by the miniaturization effort.

DEADLINE

In order to be considered for the 1957 Miniaturization Award, entries must be received by the Awards Committee by January 31, 1958.

Life on the Chemical Newsfront



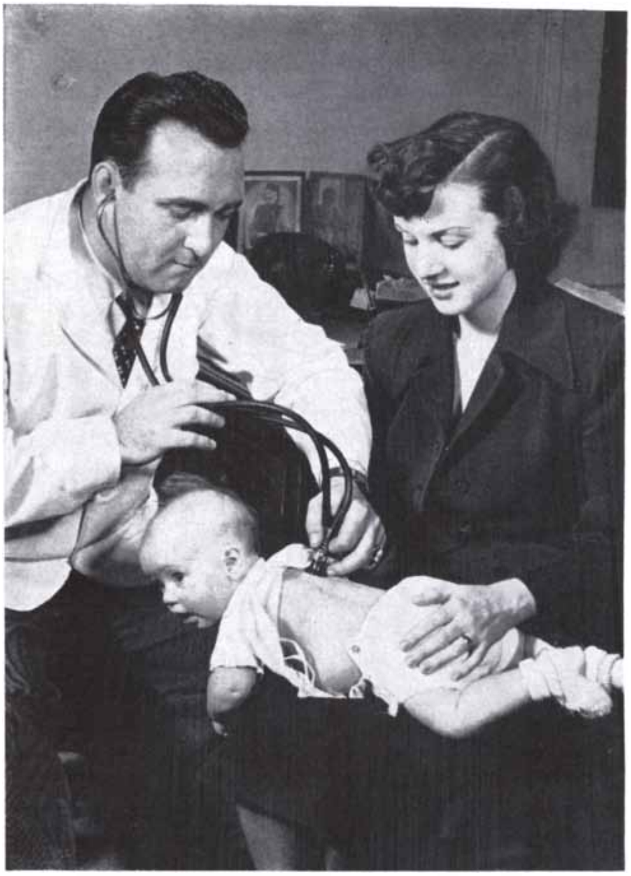
STRENGTH AND BEAUTY ARE ADDED TO SKIS made of FORMICA® *laminated plastics*. The typical hard, smooth surface adds to skiing speed. Exceptional resistance to heat and moisture keeps skis in top shape through many seasons of hard use. Special Cyanamid resins in FORMICA laminates give great impact and flexural strength to high-quality skis, golf club heads, paddle tennis racquets, and other sports items.
(The Formica Corporation)

BETTER WATER-BASE PAINTS

THE EASIEST, PLEASANTEST PAINTING YET is the promise of paints made with new water-dispersed self-emulsified CYAQUA* *resin*. Combining virtually all the advantages of solvent-type alkyds and water-base latex paints, they brush easily, evenly and thoroughly, even over glossy surfaces. Missed spots—or "holidays"—can be touched up within minutes or hours without showing lap lines. Odor is pleasant, and brushes, rollers and spills can be rinsed easily with water. Touch-dry in minutes, CYAQUA resin-based paints withstand frequent scrubbing.
(Plastics and Resins Division)

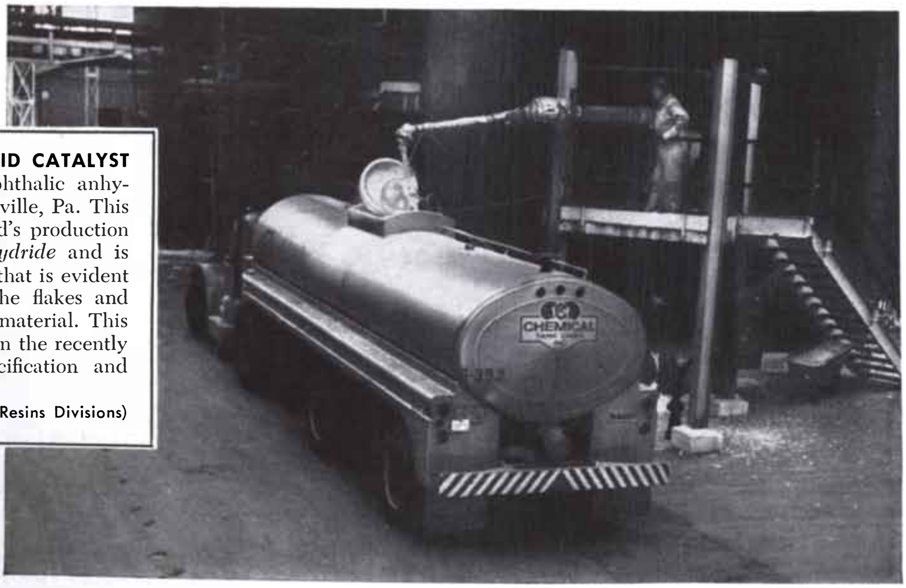
A NEW, HIGHLY EFFICIENT THICKENING AGENT for all types of water-base paints is PAM 200 *polyacrylamide*—a new high-molecular weight grade of polyacrylamide only recently introduced. Unusually low concentrations of this water-soluble polymer are sufficient to give paints excellent spreading, leveling and pigment suspension properties. PAM 200 can be dissolved easily in cold water with conventional equipment without forming "fish eyes" of undispersed polymer. Warming does not affect its solubility. (New Product Development Department)

SEWING AND CUTTING ARE MADE EASIER in textiles finished with CYANATEX® 3130 *softener.* Fibers are lubricated and softened to give good drape and a soft, full "hand." CYANATEX 3130 is readily dispersed in water and may be used in conjunction with many other finishing agents in conventional process equipment. It is highly resistant to yellowing, free of odor, and does not affect fastness or shade of dyed fabrics. (Organic Chemicals Division)



ESSENTIAL TO BODY CELL PRODUCTION, *folic acid* is receiving increased attention as a nutritional supplement. Deficiencies lead to certain types of anemia—a danger particularly present during the highly increased cell production of pregnancy. Prenatal diets often call for folic acid in supplemental form to avoid blood abnormalities in both mother and child. Found in liver, yeast and leafy vegetables, folic acid is manufactured by Cyanamid for professional use and for the manufacture of multivitamin preparations.

(Fine Chemicals Division)



THE APPLICATION OF NEW FLUID CATALYST TECHNIQUES to production of phthalic anhydride is well under way at Bridgeville, Pa. This new plant has increased Cyanamid's production capacity for AERO* *phthalic anhydride* and is yielding an extremely pure grade that is evident from the unusual whiteness of the flakes and the brilliant clarity of the molten material. This new product quality is presented in the recently published Cyanamid "P.A." specification and typical properties.

(Industrial Chemicals and Plastics and Resins Divisions)

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LETTERS

Sirs:

I must take exception to Theodore H. Ingalls's presentation of the causes of congenital deformities [SCIENTIFIC AMERICAN, October]. He says correctly that embryos exposed to German measles and radiation may be deformed. He provides experimental evidence that fish and mouse embryos deprived of oxygen may give rise to deformed fish and mice. But where is the evidence for the prenatal effects of "deep anesthesia and surgery, automobile accidents . . . and so on"? Or the evidence for the statement that "we may be able to prevent much blindness, mental retardation and cerebral palsy . . . by seeing to it that pregnant women avoid deep anesthesia or severe hemorrhage"? And how, at present, can we "make inroads into the number of cases of mongolism by paying more attention to the pregnancies of older women"? What is known of the effect of long airplane flights on the outcome of pregnancies? Certainly very little is known from experiments on mice exposed to low pressure in chambers simulating altitudes of 25,000 to 30,000 feet, equivalent to the altitude of the top of Mount Everest. Even in mice, do we know anything about defects caused by exposure to oxygen pressure equivalent to 20,000, 15,000, 10,000 feet or less?

Embryologically speaking, given defects originate at specific sensitive periods. Whatever brings forth malformations can only work by way of developmental systems. That holds both for external agents and genes. To produce cleft palate in mice by drastic environmental stress does not explain why genetically predisposed mice kept under normal conditions bring forth young with cleft palate. To my knowledge no prenatal therapy has yet prevented the development of genetic cleft palate in mice—a feat which would have a more direct application to prenatal pediatrics than the causation of abnormalities by excess strain to which few women, if any, are exposed.

The examples of the birth of mongoloid babies after carbon monoxide poisoning, automobile collisions and anesthesia carry little weight by themselves. Mongoloid babies unfortunately occur at a frequency of about one in 600, so that the coincidence of unusual accidents or treatment with such a birth is likely to be a matter of chance. Of course mongolism is well known to be correlated with a nongenetic factor, maternal age, a fact which offers hope for eventual prevention. Yet decisive properties are inherent in the egg from which a mongoloid develops. This is shown by the evidence from twins: mongolism nearly always affects the two partners of a one-egg pair of twins, and affects alike those from two eggs only rarely. Environmental stress to two fetuses in the same uterus should affect twins derived from two eggs in the same way as twins from one egg. But the predisposition of a single egg results in one-egg twins, who are both affected, while predisposition of one out of two eggs results in two-egg twins of which only one is defective.

Ingalls's article also includes material which has no direct bearing on his argument. The "fatal blood disease called erythroblastosis" (fortunately, often it is not fatal) is due to Rh-gene–controlled interactions between mother and fetus, and not to independent environmental conditions. Blindness caused by the exposure of premature babies to excessive oxygen pressure is an affliction acquired outside of the mother, not *in utero*.

I share Ingalls's belief that prenatal therapy has an important future, but I do not believe that we yet have any control over the thousands of cases of genetically conditioned defective infants who are born yearly to parents whose hopes can only be disappointed by premature assurances, and who are subjected to tragic experiences and unnecessary feelings of guilt not by avoidable behavior but by genetic fate.

CURT STERN

University of California
Berkeley, Calif.

Sirs:

Since it is impossible in a letter of reasonable length to take up one by one and in detail all the points that have been raised, I will restrict myself to highlights. First, however, let me say that for a discussion of evidence which indicates that "we may be able to prevent much blindness, mental retardation and cerebral palsy . . . by seeing to it that pregnant women avoid deep anesthesia or severe hemorrhage," I refer the interested person to my 30-page article on prenatal pediatrics published in *Advances in Pediatrics*, Vol. 6, 1950. The outlook for controlling German-measles–caused anomalies alone illustrates how practical this kind of approach may be and how promising is the outlook. Many of us are working toward this goal.

As for the question about the potential risk of long and high (*e.g.*, transoceanic) flights during early pregnancy, I quote my answer when the question was raised at a parents' meeting on the subject of possible causes of mental retardation: "Dr. Ingalls was asked whether flying was dangerous during pregnancy because of changes in the amount of oxygen present in the mother's environment. He pointed out that cabins are pressurized but felt that short flights were on the whole safer than long ones, and stressed that the baby *in utero* is able to survive long (by comparison with the adult) spells of lack of oxygen. It was not the flight *per se* that was the sole consideration, but the additive possibilities of many things working together: influenza, anemia, hypothyroidism, varicose veins or heart trouble in the mother. There is no reason why a woman couldn't have all of these things together. The flight might be 'the straw that broke the camel's back' for her, whereas her healthy sister might not be bothered at all."

In reply to Stern's query, "Even in mice, do we know anything about defects caused by exposure to oxygen pressure equivalent to 20,000, 15,000, 10,000 feet or less?", the answer is yes. Murakami has made such experiments in Japan and finds measurable effects from

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exposures as low as 16,500 feet for five hours. Hence my emphasis on the length of a flight.

Such factors as smoking are also involved. There is evidence that a confirmed smoker may start with a disadvantage of several thousand feet in altitude toleration because of an accumulation of carbon monoxide in the hemoglobin. Even a cabin pressurization equivalent to 8,000 feet is not invariable in the same sense that plane structure is. As I see it, the matter of additive hazards is much more to the point than the risk of a single hazard such as that outlined by Stern.

As for inhibiting the expression of a genetically determined defect, can't many of the accomplishments of medicine and preventive medicine be so construed? I think that whether "few women, if any" are exposed to excess strain during pregnancy is beside the point. The point is whether their babies are occasionally exposed to critical stresses which initiate many of the maldevelopments not seen until birth. The German measles story alone indicates that deformities once thought to be inherited may be acquired. Physicians would hardly consider the control of German measles a genetic measure.

I am not sure what point Stern is trying to make when he advances mongolism as if it were of genetic origin and says that mongoloid births "unfortunately occur at a frequency of about one in 600." I look to the day when this rate will be lowered significantly. He goes on to say that "mongolism nearly always affects the two partners of a one-egg twin pair." This is a fact; but I do not find it difficult to interpret, for identical twins share the same intra-uterine milieu and are of the same gestational age when maternal adversity registers its impact. As for controlling mongolism by genetic methodology alone, I regard this as a pious but wholly unrealistic hope. One prominent geneticist came to the conclusion less than 30 years ago that mongolism might be "due to the simultaneous presence in the germ cell of five pairs of recessive factors or two dominant and four pairs of recessive factors carried in as many different chromosomes." What does this really mean? Granted even that it is correct, what does the information hold for mothers of mongoloid children, women who may give birth to babies in the future, or for physicians who are working to ameliorate the condition or, better yet, to prevent it?

As for the suggestion that some material in the article has no direct bearing on my argument, I am in only partial agreement. For example, the severity of genetic ("Rh-gene-controlled") interactions are also affected decisively by wholly environmental circumstances—prior transfusion of a mother with Rh-positive blood, to name one. I do agree with Stern about oxygen-induced blindness being acquired after the premature baby has been born, and for this reason had requested the editors to delete the sentence. However, a premature baby is no less a fetus merely because it has been born and the editors chose to leave the sentence in.

Finally, I do not believe that obstetricians and physicians will concur that work of the kind reported raises "unnecessary feelings of guilt." Guilt is no more involved than it is when a person develops paralytic poliomyelitis; one works to avoid the "tragic experience."

THEODORE H. INGALLS

Department of Epidemiology
School of Public Health
Harvard University
Boston, Mass.

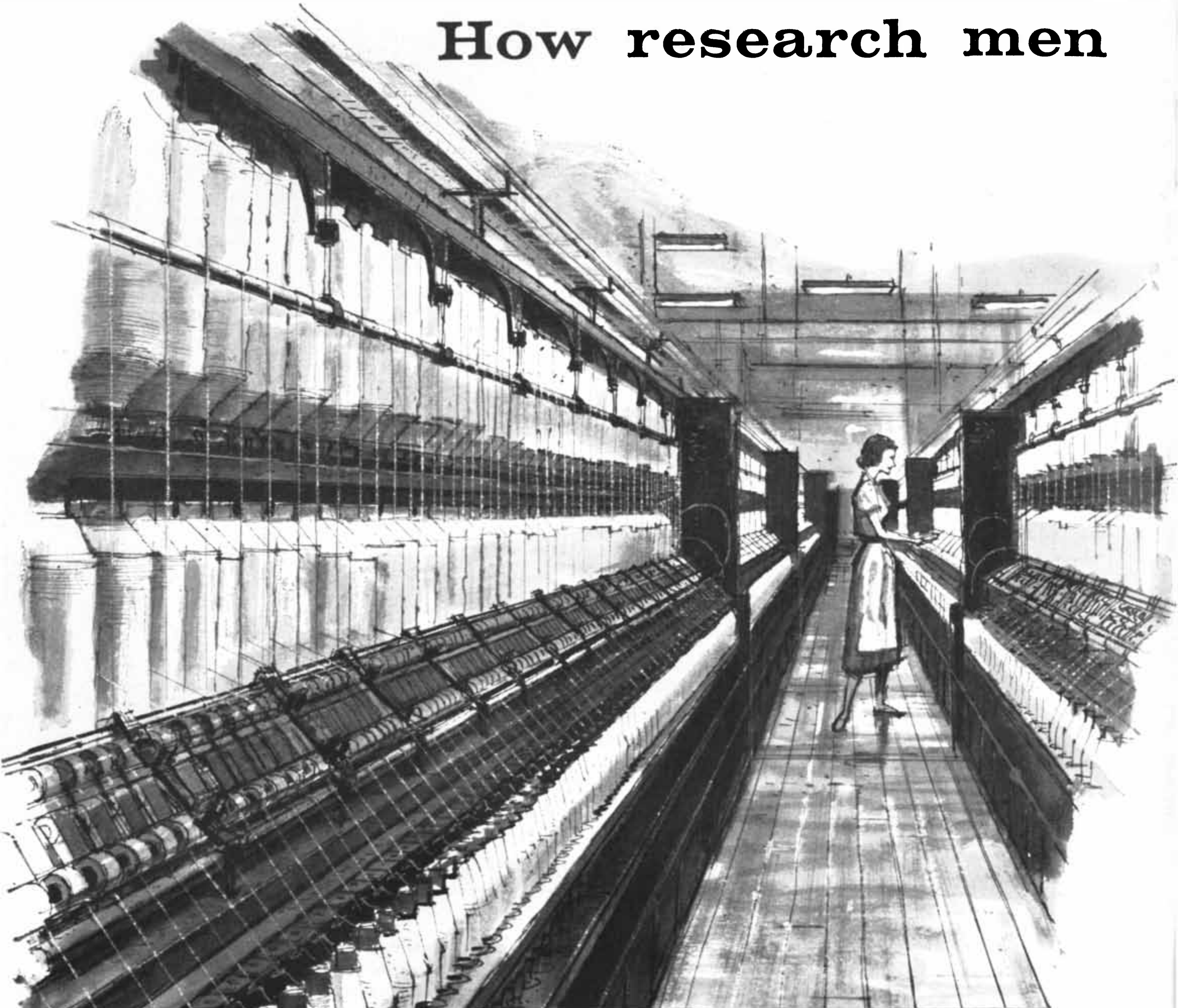
Sirs:

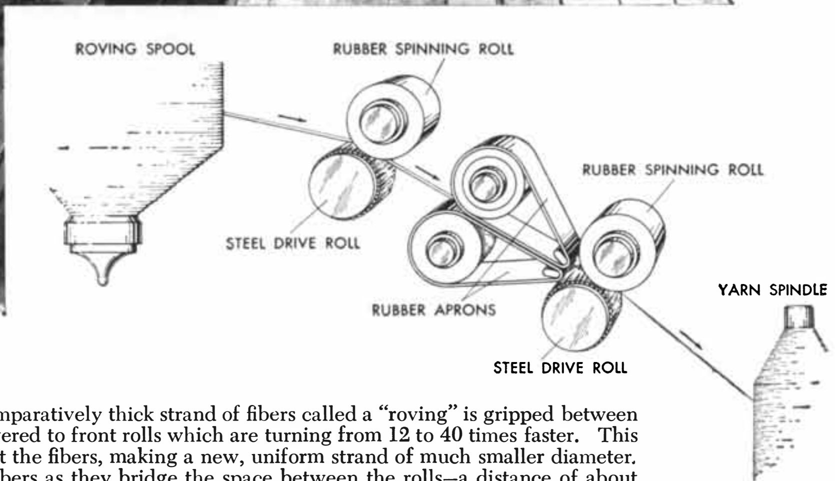
I cannot help suggesting that many of your readers may find vastly more pleasure and stimulation in Alexandre Koyré's new book, *From the Closed World to the Infinite Universe,* than James R. Newman's review in your October issue would hint. (Is it, for example, quite fair to describe as "256 pages, gravid with footnotes," a book in which all the notes are collected, together with bibliography, on pages 277 to 304?) Both my admiration for Newman's work and the kindness with which he has described my own *The Copernican Revolution* in the same review would normally dictate silence. But since my approach to the history of science owes more to Koyré than to any other living scholar, I am both surprised and embarrassed to discover that, while my book is found to provide "encouraging evidence of a fresh turn in the study of the history of science," Koyré's exemplifies "the orthodox approach" from which historians of science are urged by Newman to depart.

THOMAS S. KUHN

Departments of History and Philosophy
University of California
Berkeley, Calif.

How research men





In yarn-spinning, a loose, comparatively thick strand of fibers called a "roving" is gripped between revolving rear rolls and delivered to front rolls which are turning from 12 to 40 times faster. This difference in speed draws out the fibers, making a new, uniform strand of much smaller diameter. Rubber aprons control the fibers as they bridge the space between the rolls—a distance of about four inches. The thread continues on to a "traveler" (not shown) and spindle which turn at about 10,000 rpm, giving the yarn the twisting it needs to lock the fibers in place.

taught rubber to spin yarn

In about the time it takes to read this sentence, a set of rubber rolls and bands on a modern spinning frame can transform an inch of wispy cotton fibers into more than three feet of hard-to-break yarn.

These rubber rolls and bands—textile men call them "cots" and "aprons"—do this exacting job by gently drawing out cotton fibers that naturally vary in length. The long and short fibers are held in place until all can be twisted together permanently. These rolls and bands look ordinary enough, but they've got some highly developed spinning skills built into them.

The rolls, for example, had to "learn" to resist lap-ups. These occur when a yarn end breaks, sticks to a spinning roll, and wraps tightly around it—usually so tightly that it must be cut loose. This takes time, and there's always danger that the roll will be cut, too.

For years, the cause of lap-ups was unknown. Then Armstrong research chemists found that moisture layers on the fibers and rolls contain electrical charges that attract fibers to the rolls. After further study, these chemists discovered a cure. They added a special electrolyte to the synthetic rubber used in making the rolls. Lap-ups ceased to be a problem!

Armstrong research men also had to teach spinning rolls to resist "eyebrowing." An eyebrow is a clump of waste fibers that builds up on the front of the felt-covered clearer board which rests on the spinning rolls and wipes them clean. When "eyebrows" form, they're apt to fall onto the yarn and break it. Or they may be spun into the yarn, making it uneven.

This time the answer was found by adding particles of cork or wood fiber to the synthetic rubber mix. These particles act like thousands of tiny fingers, grabbing the waste fibers and carrying them back under the clearer board pads where they can do no harm.

The rubber aprons that help control the yarn as it moves between the rolls also needed a few lessons. The outside surface must have enough friction so that the bottom apron will drive the top without slippage. Yet the inside surface must turn smoothly around a nose bar whose radius is ⅟16″ or less. The Armstrong solution: two different rubber compounds, one for each surface, vulcanized together with a nonstretch interliner between. This "sandwich" is given a special chemical bath which conditions the rubber surfaces so that their frictional properties are exactly right for top quality spinning.

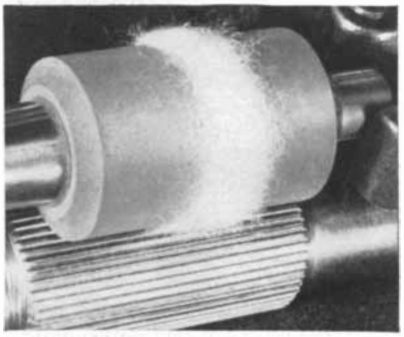
As a result of this research and development, yarn is being spun better and more economically than ever before. And there's a better than even chance that the yarn for the clothes you wear was spun on cots and aprons "educated" by Armstrong.

Although originally compounded for use in textiles, Armstrong rubber products have found wide use in other fields. The rubber rolls are handling web and film materials for many industrial firms. And many drive and conveyor belt problems are being solved by seamless, nonstretch Armstrong Flat Belts which use much the same construction as that patented for Accotex® Aprons. For details, write to Armstrong Cork Company, Industrial Division, 8212 Inland Road, Lancaster, Pennsylvania.

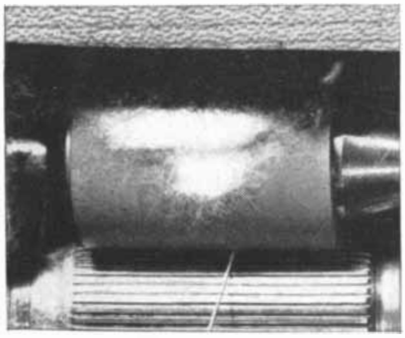
Armstrong Industrial Products

... USED WHEREVER PERFORMANCE COUNTS

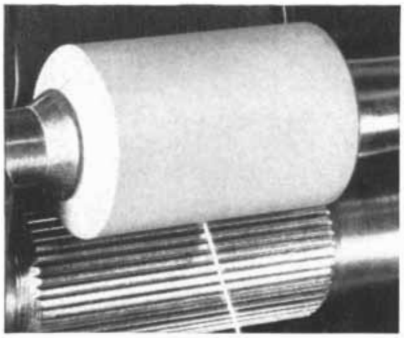
ADHESIVES
CORK COMPOSITION
CORK-AND-RUBBER
FELT PAPERS
FRICTION MATERIALS



If yarn breaks after being drawn under a spinning roll, microscopically-thin water film holds the broken end to the roll—causing a lap-up. Tiny electrical charges in the water film actually set up an adhesive force, bonding the fiber to the roll.

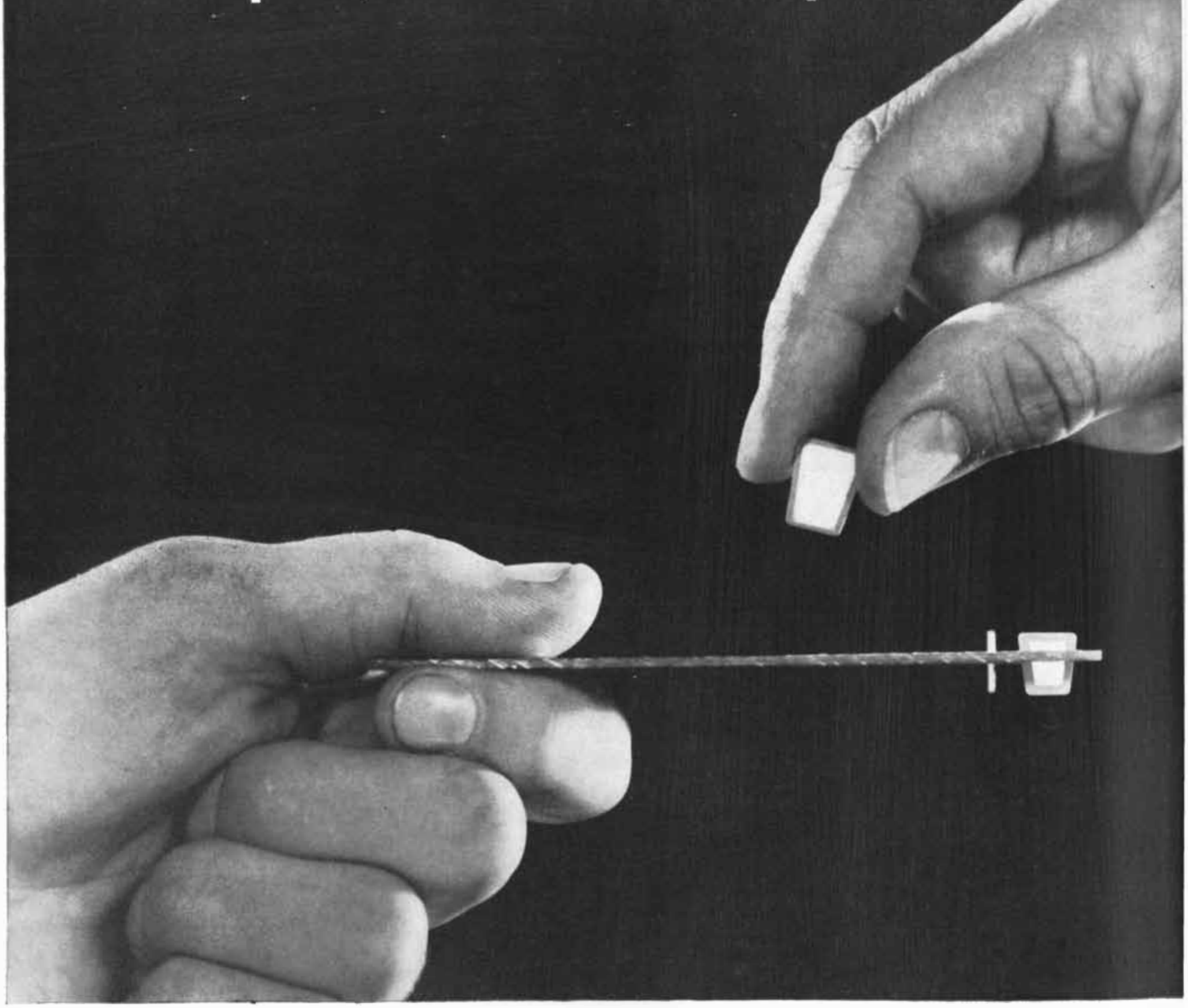


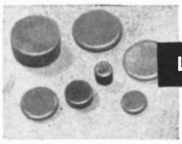
As yarn is spun, flat felt-covered clearer boards, placed on the spinning rolls, pick up waste fibers. But if the spinning surface of the roll is not rough enough to push waste back under the clearers, "eyebrows" may form—and drop into the yarn.



The lapping problem was solved by adding an electrolyte to the rubber which neutralizes the electrical charges in the water film. Eyebrowing was ended by mixing cork particles into the rubber. These carry waste fibers back under the clearers.

Forget leads, insert Wejcap capacitors, see costs of print board assemblies drop





Lead Metaniobate

A piezoelectric material recently developed by General Electric, Lead Metaniobate remains remarkably stable over the temperature range from —54°C to 265°C, an important fact in high-temperature instrumentation devices. It displays superior aging characteristics compared with other ceramic piezoelectric bodies. The high Curie temperature (570°C) allows repeated heat cycling with no effect on electrical output.

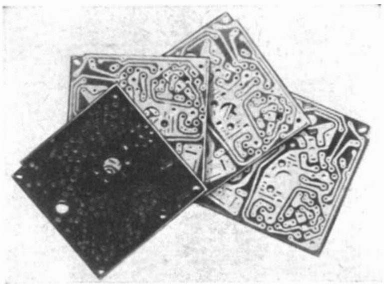
Encapsulated RC Networks

A new series of encapsulated RC networks is now available from General Electric that replaces a host of individual resistors and capacitors. The price saving can be ten percent or better. The assembly saving in print wire boards—inserting one unit instead of five or ten—averages about 67 percent. Furthermore, this small RC network results in a smaller overall assembly, cutting board costs.

New stabilized types or general purpose types cost up to 35% less, resist breakage and moisture.

Wejcap capacitors were specially developed to let you realize more fully the economy and design advantages of printed boards. They are a product of General Electric research into the high density, high strength properties of improved barium titanate. They have no leads to bend or break, or that require extra time to crimp and align. Extensive production use proves Wejcap capacitors are practically unbreakable and resist moisture absorption. They are available in general purpose types, or in the new stabilized types that maintain their value at room temperature to within ± 20% of the nominal value.

How much can you save? Wejcap capacitors cost up to 35% less than other capacitors. Production runs show that four Wejcap capacitors can be inserted in the time it takes to put in three ordinary capacitors. The total cost and assembly savings will be appreciable, even if you apply only three Wejcap capacitors to your production chassis.



Thru-Con* print wire boards. Now you can design a compact wiring pattern on both sides of the board without the cost of further processing to connect them. The "Thru-Con®" additive technique plates through the holes at the same time it plates the wiring pattern. This permits high-speed dip soldering remarkably free from rejects. No special eyelets or pre-cleaning are required. Assembly weight is reduced and inventory is simplified.

Sample Wejcap capacitors and other General Electric components—plus technical data—are yours for the asking. Just fill in the coupon below. *Specialty Electronic Components Dept., General Electric Company, West Genesee Street, Auburn, New York.*

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Manager of Sales, Specialty Electronic Components Dept., General Electric Company. West Genesee St., Auburn. New York

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☐ **Ferrites** ☐ **Wejcap Capacitors**

☐ **Thru-Con® Print Wire Boards**

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TRIGA

A training, research, and isotope-producing reactor, specially designed to permit a complete on-campus training and research program. Inherently safe, this 10 kw, multi-purpose reactor meets the needs of university departments working in various areas of nuclear science. Custom isotope production for on-campus or local service use.

IRGA

Designed for custom production of radioisotopes, including the *short-lived,* at user's site of operation. Simple in concept and safe in operation, this 10 kw, isotope-producing reactor allows continuous or intermittent operation without special staff attention. Economical through safety, it opens the door to savings — particularly for industry — through radioisotope applications.

New UZrH Core Provides Inherent Safety In Three New General Atomic Reactors

The solid homogeneous UZrH system, invented, developed and tested by the John Jay Hopkins Laboratory for Pure and Applied Science, is a new core concept that provides inherent reactor safety. The *prompt,* negative temperature coefficient of the system allows all available excess reactivity to be introduced suddenly without damage to the reactor. Inherent reactor safety is achieved through the new UZrH fuel elements which have metallic properties. REGA, TRIGA, and IRGA, the three new General Atomic reactors using this core, can be operated at useful power density and do not rely upon electronic-mechanical devices for safety.

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50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

DECEMBER, 1907: "With the death of Lord Kelvin on the 17th of December, in the 84th year of his life, there was ended a career full of usefulness to mankind. William Thomson, first Baron Kelvin, was born in Belfast on the 26th of June, 1824. His scientific education commenced at the age of 10, for in 1834 he was a matriculated student of Glasgow University, in which his father was professor of mathematics. In 1846 he was made professor of natural philosophy at Glasgow, serving in that capacity for a space of over 50 years. From 1857 to 1858, and from 1865 to 1866, he acted as electrician of the Atlantic cables, inventing in this capacity the mirror galvanometer and the siphon recorder, neither of which, it is interesting to note, he wished to patent, desiring to give them to the world as a physician gives his discoveries. In 1892 he was made a baron, because of his services to mankind. The scientific achievements of this remarkable man are largely in the nature of inventions; in them mechanical complexity is notably absent, owing to remarkable grasp of the underlying theoretical principles."

"The American minister at Stockholm has advised the State Department that the Nobel prize for physicists has been granted to Prof. Albert A. Michelson. Prof. Michelson is head professor of physics in the University of Chicago, of which faculty he has been a member since its founding in 1892. His first notable invention was an instrument for measuring the velocity of light, for an improved method of which he has now received the Nobel prize. He is also the inventor of a spectroscope that has a higher resolving power than any other instrument in use, and of several instruments for measuring distance by means of light waves. One of his most famous inventions is an interferometer that not only measures light waves but counts them as well."

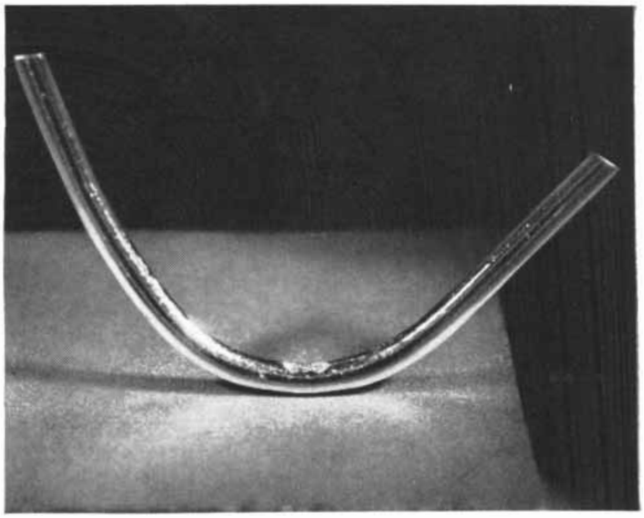
"No one at home or abroad has shown so much energy in the solution of the questions of high-speed air and water navigation as Santos Dumont. The rapidity with which he changes from experimentation with an aeroplane to skimming the water with a hydroplane, and then back again to an aeroplane, is truly amazing. The latest aeroplane, which is Santos Dumont's 19th machine, is the lightest and simplest flyer which he has thus far produced, which accounts for its rapid construction in two weeks' time. 'No. 19' is a monoplane made up of two wings set at a dihedral angle. It has a double-opposed-cylinder gasoline motor of the air-cooled type, designed and built in 10 days by the engineers of the Duteil and Chalmers Company of Paris. The gasoline tank is very small. It holds one liter (about a quart). M. Dumont was well satisfied with the trial flight, about which he spoke: 'I had the aeroplane well under control, and never had such a sense of security, even in my airships. The flight was stopped by a somewhat curious accident, that is, a lack of gasoline.' "

"The past season of the British School of Archaeology in Egypt, the work of which has been carried out under the direction of Prof. Flinders Petrie, has been of unusual value. It resulted not only in bringing to light more evidences of the earliest eras of Egyptian civilization, but it also demonstrated the prevalence of this civilization over a wide tract of country. At Rifeh, near Asyut in Upper Egypt, a large cemetery was excavated which contained a unique series of 'soul houses'; little models of residences which were placed upon the grave for the accommodation of the liberated soul."

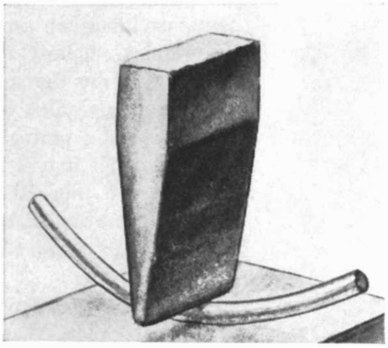
SCIENTIFIC AMERICAN

DECEMBER, 1857: "An interesting paper was recently read before the Academy of Sciences in Paris on an expedition sent out to the East Indies in 1854, by the King of Prussia, for scientific purposes. The members of the expedition consisted of three brothers, namely, Hermann, Adolphus and Robert Schlagentweit. The highest of all the summits known throughout the world appears by the measurements of Hermann Schlagentweit to be the Gahoorischanke, situated in the eastern portion of Nepaul—the same announced as such by Colonel Waugh, but called by him Mount Everest, because he had been

Thermo-compression bonding—



Wire bonded to germanium by thermo-compression technique (enlarged). Wires only 1/10 the breadth of a human hair have been successfully anchored to germanium wafers only three hairs thick. The bond may be an ohmic contact or rectifying contact by adding suitable impurities to the wire and the semiconductor.



One method of thermo-compression bonding. A heated wedge presses a wire against a heated semiconductor with enough force to deform the wire. Adhesion occurs in seconds.

new way to join metal to semiconductors

Thermo-compression bonding provides a new way to attach a wire to a semiconductor. It calls for heat and pressure—nothing else. The wire and the semiconductor are moderately heated, then pressed together under moderate pressure. The resulting bond is very strong—stronger actually than the wire. No chemical flux or molten metal is required.

Eliminating molten metal provides an enormous advantage in fixing electrical connections to transistors. That's because molten metal tends to spatter and spread uncontrollably over the surface of a semiconductor. And it may alloy with the semiconductor to alter its all-important crystalline structure and chemical purity. Thermo-compression bonding easily and quickly makes a strong permanent electrical connection without damaging the semiconductor. Furthermore, the lead may be attached to microscopic areas and precisely positioned, a most valuable aid in the construction of high-frequency transistors.

Thermo-compression bonding will speed the production of transistors . . . the transistors needed to fill all the new jobs Bell Laboratories finds for them in the quest to provide still better telephone service to our growing country.

At Bell Labs Howard Christensen and Orson Anderson discuss their discovery of new bonding principle with Peter Andreatch, Jr., who collaborated in the studies.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT unable to ascertain its real name in the plains of Hindostan. This peak is somewhat more than 29,000 feet in height. The other two brothers, Adolphus and Robert, penetrated by different roads into the central parts of the Himalaya, Kumaon, and Gurwahl; they then visited Thibet in disguise, and ascended the Ibi-Gamine, 22,260 feet in height, that being, we believe, an altitude never before attained in any part of the world."

"We learn from the London *Times* that extensive preparations are now being made for laying the Atlantic cable next year, and that the attempt will take place in the month of June. It seems that the very kind of machinery for laying the cable which we recommended as essential to its success is being constructed. The paying-out machines are especially contrived to guard against the strain on the cable caused by the sudden pitch of the vessel, and also the brake on the wheels will be perfectly self-acting and so made that it will be impossible to place upon it more than about one third of the strain which the cable can safely be relied upon to bear."

"Capt. Meigs says that the ventilation of the new Senate Chamber at Washington will be improved by a steam fan which he is now preparing, and which is capable of throwing 90,000 cubic feet of air into the hall per minute. It will provide a complete renewal of air in the Chamber every five minutes, as the cubic capacity of the room is not over 460,000 feet. No amount of Congressional corruption can contaminate such a torrent of purity as this."

"No object-glasses of a larger size than seven inches diameter have been made of glass manufactured in England; and, notwithstanding the success of some Continental opticians, the procuring of flint-glass fit for object-lenses of a larger size seems to be still, in a considerable degree, a matter of accident. There is a telescope in the Russian observatory at Dorpat having an object-glass of nine inches diameter. Another was prepared for the King of Bavaria, of 12 inches diameter. The object-glass of Sir James South's large telescope is nearly 13 inches in diameter, and was executed in Paris of glass manufactured by Guinaud. The practical difficulties of forming a good achromatic object-glass for a telescope of large size are so great that it often costs more than all the rest of the instrument. This arises principally from the extreme difficulty of procuring disks of flint-glass above a certain size."

Photo courtesy Blackman Plastics Company, Culver City, California, and Charles Crowl Company, El Monte, California

Here's the hottest thing in flame-resistant plastics

It's a new plastic alloy and the latest answer to the need for an improved, flame-resistant, rigid plastic sheet for aircraft, automotive and industrial applications.

Among the advantages of this new material are its abilities to be made translucent and considerably lighter in weight than similar materials. It also exhibits greater impact resistance plus higher tensile strength and a high heat-distortion point. And it is post-formable and mechanically workable.

A closely guarded secret is the exact composition of this alloy. But it has been described as a unique combination of vinyl and styrene resins. It also has been revealed that PLIOVIC is the vinyl resin used. PLIOVIC was chosen because of its uniformity, rapid processing and the superior physical properties it imparts to the end product.

Just one of the many uses for the several types of PLIOVIC currently available is flame-resistant sheet. Where can you use them to advantage? For details write to: Goodyear, Chemical Division, Dept. L-9457, Akron 16, Ohio.

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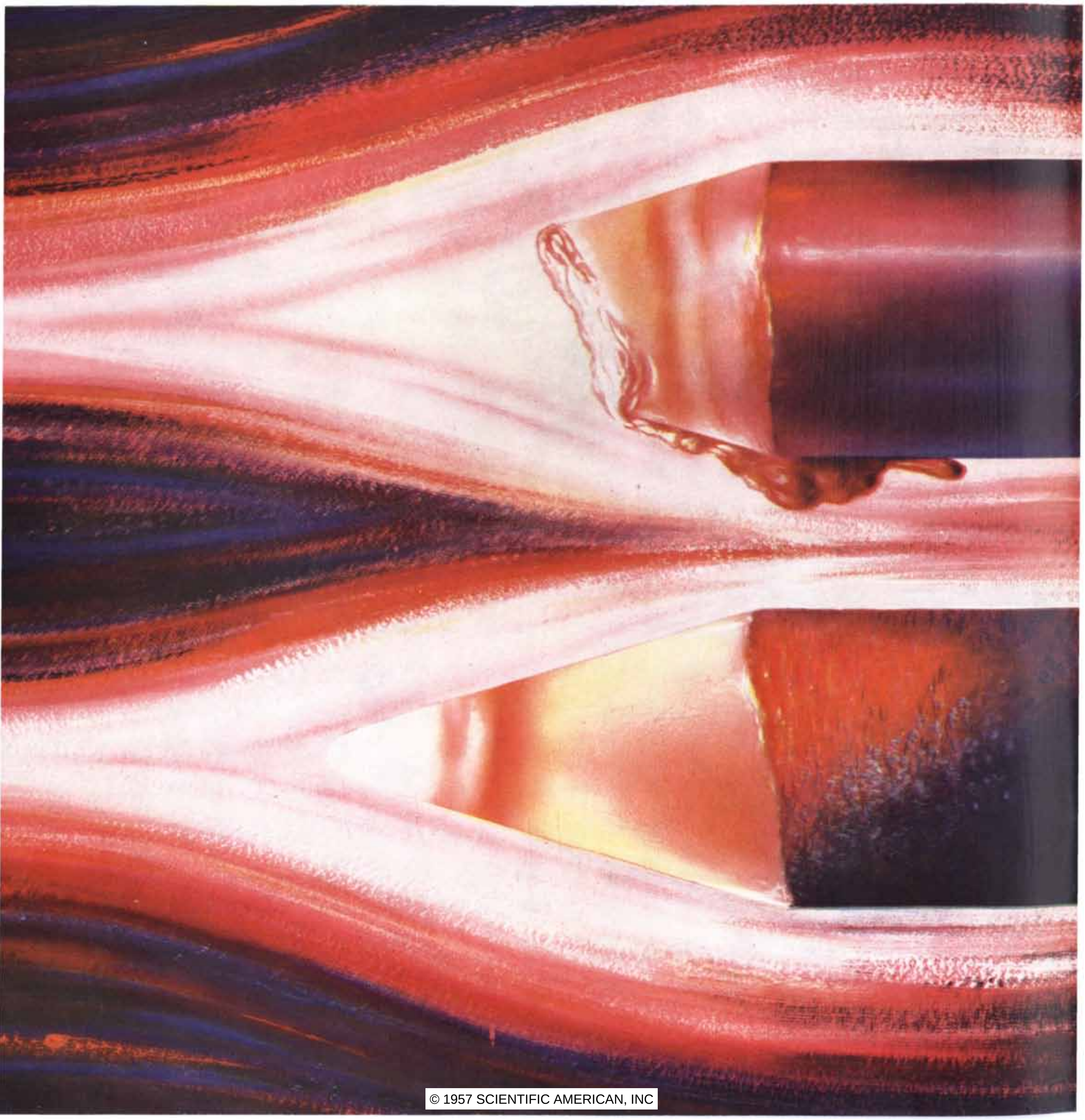
VOL. 1, NO. 1, NOVEMBER, 1957

ADVANCED MATERIALS TECHNOLOGY

The New Science of Materials for Profits

A PUBLICATION BY **CARBORUNDUM**



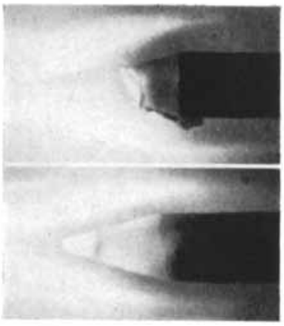
A NEW Carborundum publication of news and ideas for all concerned with advanced materials for profits to industry

Almost every industry faces barriers raised by the limitations of conventional materials. With some—aviation, for example—the hypersonic speeds of intercontinental missiles have meant finding materials capable of withstanding temperatures of more than 10,000 degrees F. In other industries, like chemical processing, the urgent demand for corrosion resistant materials continues. In still other industries, the problems of abrasion, neutron transparency and the need for special properties have stimulated the search for advanced materials and manufacturing methods.

Carborundum is publishing *Advanced Materials Technology* as an aid to all whose work demands materials and processes for severe service applications. It will be published quarterly. This publication—the first devoted exclusively to advanced materials and techniques—will prove invaluable in providing a new dimension in materials for profit.

This new service by Carborundum is offered to you without charge in the belief that it fills a definite need. AM-1

WHAT HAPPENS AT MACH 11?



The artist's conception at left shows a dramatic test simulating what happens to materials moving at speeds of Mach 11. It is based on the actual photos above of samples of 304 Stainless Steel (top) and KT Silicon Carbide exposed to a high intensity electric arc in a wind tunnel. The intense heat due to air friction causes melting of Stainless Steel, while KT Silicon Carbide retains both its shape and basic characteristics.

Typical departments in each issue will include:

1. **New Developments** . . . new products of particular interest to a wide cross-section of industry will be featured in each issue. These developments will include materials resistant to heat, corrosion, abrasion and other destructive conditions, with wide potential application throughout industry.
2. **A "look ahead editorial"** authored by General Leslie E. Simon, Vice President and Director, Research and Development Division of The Carborundum Company, will talk about the future of research, today and tomorrow, at Carborundum.
3. **Materials Symposium** . . . An exchange of ideas feature designed to encourage reader participation. Essentially a problem and solution treatment. Designed to provide maximum benefit to all industry.
4. **New Product Spotlights** . . . A capsule treatment of new products and new applications for old products of widespread interest to almost every segment of industry.
5. **An "Ask the Man from Carborundum"** department devoted to highlighting the service availability and practical "know-how" of the Carborundum technical man in the field.

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HAYNES Alloys solve the

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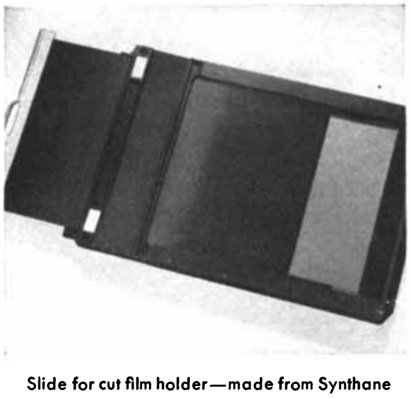
10 Years' Service at 1600 to 1800 deg. F.

Rotors and impellers made of MULTIMET alloy are being used to circulate the atmosphere inside heat-treating furnaces where temperatures range from 1600 to 1800 deg. F. They are expected to last 10 years even though they are exposed to both reducing and oxidizing conditions.

take it in color

and you put Synthane laminated plastics to work



Slide for cut film holder—made from Synthane sheet because Synthane is opaque to infra-red rays.

At first glance the connection between color photography and Synthane laminated plastics may seem obscure. Actually, Synthane has long been at home in the manufacture and processing of film and in the developing of the finished picture.

Many types of rolls, loop sticks, and structural parts made of Synthane are used by the film manufacturer. Racks, film sprockets, reels and rollers employ Synthane in developing processes. In the infancy of color pictures (and ever since), racks and reels made of Synthane proved to be exactly what were needed to resist developing solutions, prevent film fogging through contamination. Film holder slides and various parts for cameras are other uses of Synthane in photography.

The photographic industry needs Synthane for its unique combination of properties. Resistance to moisture and chemicals, non-fogging qualities, its hard, smooth surface are all important characteristics. Synthane is tough, light in weight (half the weight of aluminum) and easily machined. These and many other chemical, electrical and mechanical properties make Synthane valuable throughout the length and breadth of industry.

Over 30 grades in sheet, rod or tube form or completely fabricated by us are looking for work with you. Write for information.

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LIGHT WEIGHT

EASILY MACHINED

MECHANICAL STRENGTH

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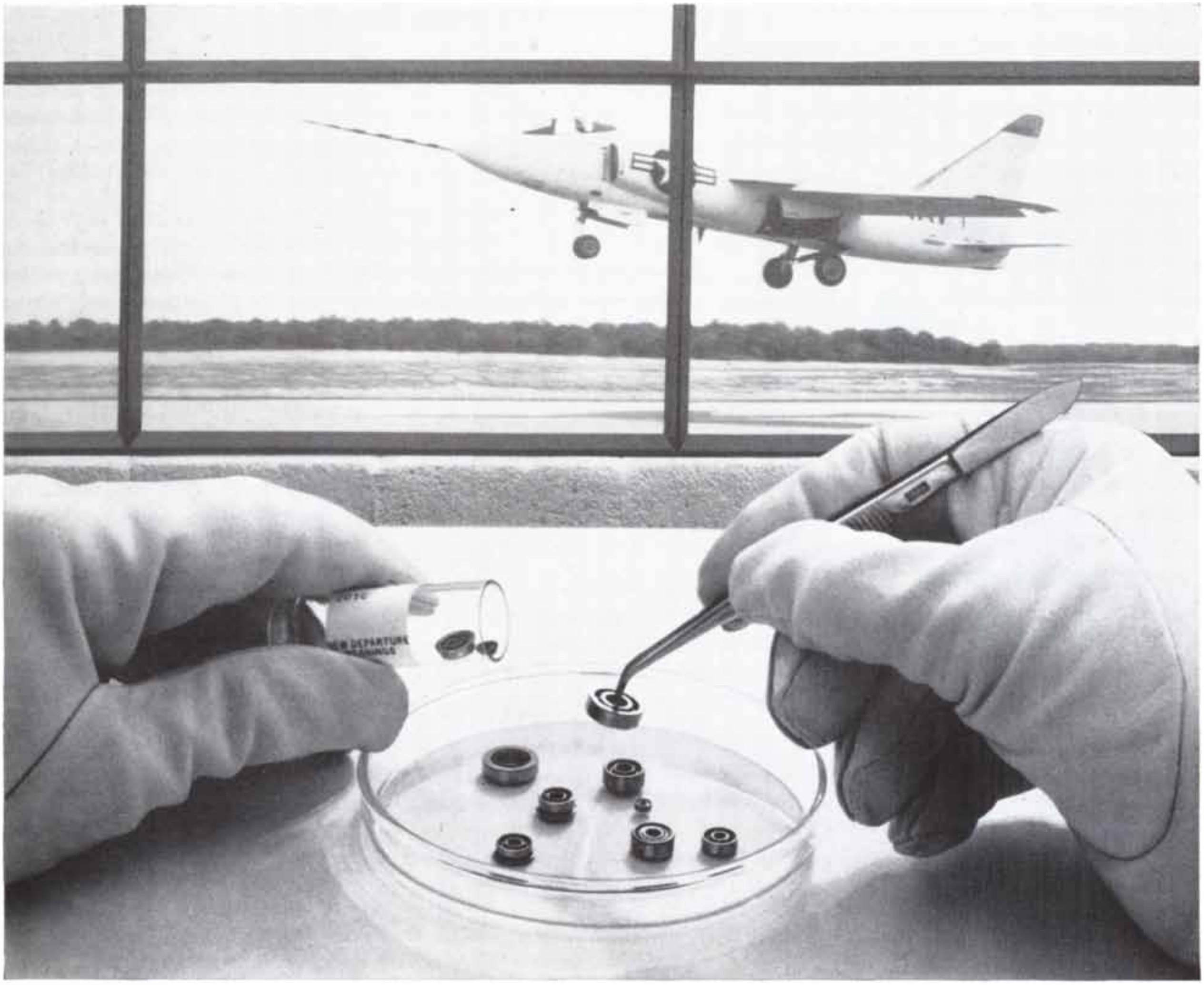

It certainly is a small world !

turning point of modern industry

Aircraft and missiles are shrinking our world! And as speeds and distances increase, component guidance parts become smaller. Yet, accuracy and reliability must reach new highs. For this reason New Departure's complete line of miniature instrument ball bearings is of great importance to leading aircraft and missile manufacturers. And deservedly so! For every step of ultra-precise manufacture . . . from initial research to final packaging in surgically clean surroundings . . . assures performance to fill the most exacting need.

If your engineering problem is dimensionally small, call on the services of a New Departure ball bearing engineer. He has the complete facts on miniature ball bearings at his fingertips.

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NEW DEPARTURE

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NOTHING ROLLS LIKE A BALL

THE AUTHORS

FRED L. WHIPPLE and J. ALLEN HYNEK ("Observations of Satellite I") are, respectively, director and associate director of the Smithsonian Institution's Astrophysical Observatory in Cambridge, Mass. Whipple, who also is chairman of Harvard University's department of astronomy, was born at Red Oak, Iowa, in 1906. He joined the Harvard astronomy staff in 1931, after acquiring a Ph.D. at the University of California. During World War II he won a Presidential certificate of merit for work in the Radio Research Laboratory of the Office of Scientific Research and Development; he has received medals for independently discovering six comets and for his pioneer work in photographing meteors. His hobby is growing roses. Hynek comes to the Smithsonian Observatory from Ohio State University, where he was professor of physics and astronomy and astronomer of the Perkins Observatory. An expert on stellar spectroscopy, he was born in Chicago and received a Ph.D. in astrophysics from the University of Chicago in 1935.

WILLIAM J. L. SLADEN ("Penguins") became medical officer of a British Antarctic expedition shortly after graduating from the Middlesex Hospital of the University of London. While he was a student he saw wartime service on an ambulance train and as casualty officer and house surgeon in London hospitals. At the University of London, where Sladen held a full scholarship, he broke records in cross-country running, captained several running teams and was chairman of the Athletic Union. In the Antarctic he was physician to members of the expedition, served as postmaster and justice of the peace, collected birds and plants, produced three educational films which have since circulated all over the world, and under primitive conditions carried out experiments in bacteriology which later earned him a doctorate in medical research from his University. In 1955 Sladen acquired another doctorate from the University of Oxford, where he did research on penguins under David Lack. He then married a University of London entomologist and came to the U. S. as a Rockefeller Fellow at the Johns Hopkins University.

IRVINE H. PAGE ("Serotonin") shared in the discovery of serotonin at the Lilly Laboratory for Clinical Research in 1946. Born in Indianapolis, he studied chemistry and earned an M.D. at Cornell University, then interned in a New York hospital before going to Germany in 1929 to head the chemical division of the Kaiser Wilhelm Institute in Munich. After several years at the Rockefeller Institute for Medical Research, Page became director of the Lilly laboratory and clinic in 1937. Since 1944 Page has directed research at the Cleveland Clinic Foundation. In his spare time he plays tennis and "writes articles for people like *Scientific American.*"

RICHARD F. POST ("Fusion Power") is a physicist as the Radiation Laboratory of the University of California. Born in Pomona, Calif., he attended Pomona College. During World War II he served in the Naval Research Laboratory, where he won a Meritorious Civilian Service Award for his work on underwater sound. In 1950 he received a Ph.D. from Stanford University. He has been connected with the University of California since 1951.

J. E. WECKLER ("Neanderthal Man") is chairman of the anthropology department at the University of Southern California. He was born on an Iowa farm, raised in a Chicago suburb and graduated from the University of Chicago in 1928. For six years during the depression he worked for a Chicago manufacturer. He then returned to the University as a graduate student, intending to become an archaeologist. But contact with the cultural anthropologist A. R. Radcliffe-Brown led him to study modern communities instead. In 1940 he took a doctorate in anthropology at Chicago, and in the following years he investigated a Spanish village in New Mexico, studied race relations in Los Angeles and examined the social life of Micronesians. Weckler's research on Neanderthal man represents a return to his first love—archaeology. Teaching an elementary anthropology course made him realize the need to bring some order into the confusing array of fossil men and prehistoric sites, and the simple explanation that he devised for his students—the result of several years of careful study and thought—are here presented to the general reader.

PHILIP and EMILY MORRISON ("Heinrich Hertz") are a husband-and-wife team who have collaborated on several previous articles for SCIENTIFIC AMERICAN, the most recent being "The Strange Life of Charles Babbage" in the

a quick check of indent-depth tells you this electrical connection is safe!

first piece check guarantees electrical connections for the entire production run

There's no way to check a soldered connection—without destroying that connection! The modern Burndy crimping method affords a quick check for electrical and mechanical safety—simply by measurement of this depth of indent. The cross-section view (right) shows how this indent is designed to coin conductor and connector into intimate contact...for a strong connection, as electrically sound as the conductor itself. And the depth of indent is controlled by the installation tool! Unlike solder which can weaken at high temperatures frequently encountered by modern equipment, the Burndy crimped connection with its wide tolerance endures in all environments. Too—Burndy electrical connections get rid of human error—no skill or training is required. The control is engineered into the connector and the tool! Put a crimp on rising production costs!—send for the full story on Burndy crimp-type connections, today!

BURNDY

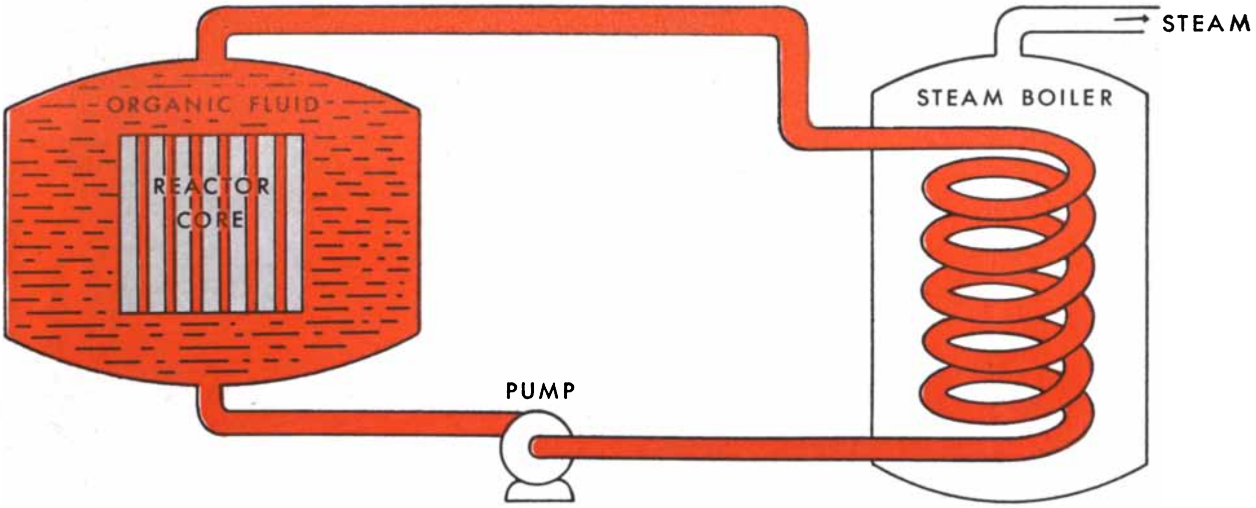
57-13

Norwalk, Connect. *Export: Philips Export Corp.* *Toronto, Canada* issue of April, 1952. In addition an article by Philip Morrison entitled "The Overthrow of Parity" appeared in SCIENTIFIC AMERICAN for April, 1957. He is associate professor of physics at Cornell University and a former student of J. Robert Oppenheimer at the University of California.

REIDAR F. SOGNNAES ("Tooth Decay") does his pioneer work on teeth at the Harvard School of Dental Medicine, where he is associate dean and Charles A. Brackett Professor of Oral Pathology. Born in Bergen, Norway, he received his dental surgeon's license *summa cum laude* from the University of Oslo in 1936. He then joined a Norwegian scientific expedition to the tiny South Atlantic island of Tristan da Cunha, whose natives have extraordinarily good teeth. This experience was described by Sognnaes and W. E. Christopherson in their book *Tristan da Cunha, the Lonely Island.* Later Sognnaes came to the U. S. where as a Carnegie Dental Fellow he obtained a Ph.D. from the University of Rochester in 1941. He spent the war years as a dental officer with the Royal Norwegian Air Force in Canada and Europe, joined the Harvard staff in 1945 and became a naturalized U. S. citizen in 1951. An article by Sognnaes entitled "The Skin of Your Teeth" appeared in SCIENTIFIC AMERICAN for June, 1953.

N. J. BERRILL ("The Indestructible Hydra") is Strathcona Professor of Zoology at McGill University in Montreal. His interest in biology was aroused during his school and college days in England, when he spent vacations along the estuaries of Devon and Cornwall; in fact, he confesses that "I like maritime life and work with marine organisms in order to be at the coast, rather than because of a special concern with marine biology as a science!" Berrill, who is a graduate of the universities of Bristol and London and a Fellow of the Royal Society, has taught at McGill since 1927; nowadays he takes his seaside vacations at his house at Boothbay Harbor, Me. He has written a number of books for the general reader, including *Sex and the Nature of Things* and *Man's Emerging Mind.*

ERNEST NAGEL, who reviews G. Spencer Brown's *Probability and Scientific Inference* in this issue, is John Dewey Professor of Philosophy at Columbia University. Nagel's essays were recently brought together in a volume entitled *Logic without Metaphysics.*



Simple, low-cost plants are the key to power from the atom at a competitive price. Sooner than you think, nuclear reactors may be as simple as a steam boiler. That's why the future of cheap atomic power looks more promising. Optimism is based on new test results with Monsanto functional fluids . . .

Blood for the veins of nuclear reactors

"Burning" fuel in the core of a nuclear reactor—theoretically—is as easy as firing coal in a furnace. The hard, practical problem has been to capture heat from the reactor and transfer it at low cost to a steam generator. Now, new test results with Monsanto synthetic fluids indicate that organic chemicals can transfer heat more economically than other materials.

Unique properties of these synthetics from Monsanto's storehouse of functional fluids break the barrier to lower costs in reactor construction. Their low vapor pressure at high temperatures eliminates the need for high-pressure equipment. Since they do not corrode common construction materials, such as mild steel and aluminum, costly metals are not required in equipment. And because these organic fluids do not emit gamma radiation even while under neutron bombardment, thick secondary shielding is unnecessary for safety.

Work by Atomics International at the National Reactor Testing Station in Idaho has already spurred plans for a commercial power reactor with Monsanto terphenyl compounds as the "coolant-moderator." Meanwhile, researchers are studying other Monsanto organic fluids, such as isopropyl biphenyl and biphenyl, which may be more desirable in certain types of reactors. Some engineers believe a mixture of organic liquids may prove to be the best coolant of all. Whichever proves best, Monsanto organic fluids promise to help ease the cost pinch on atomic power.

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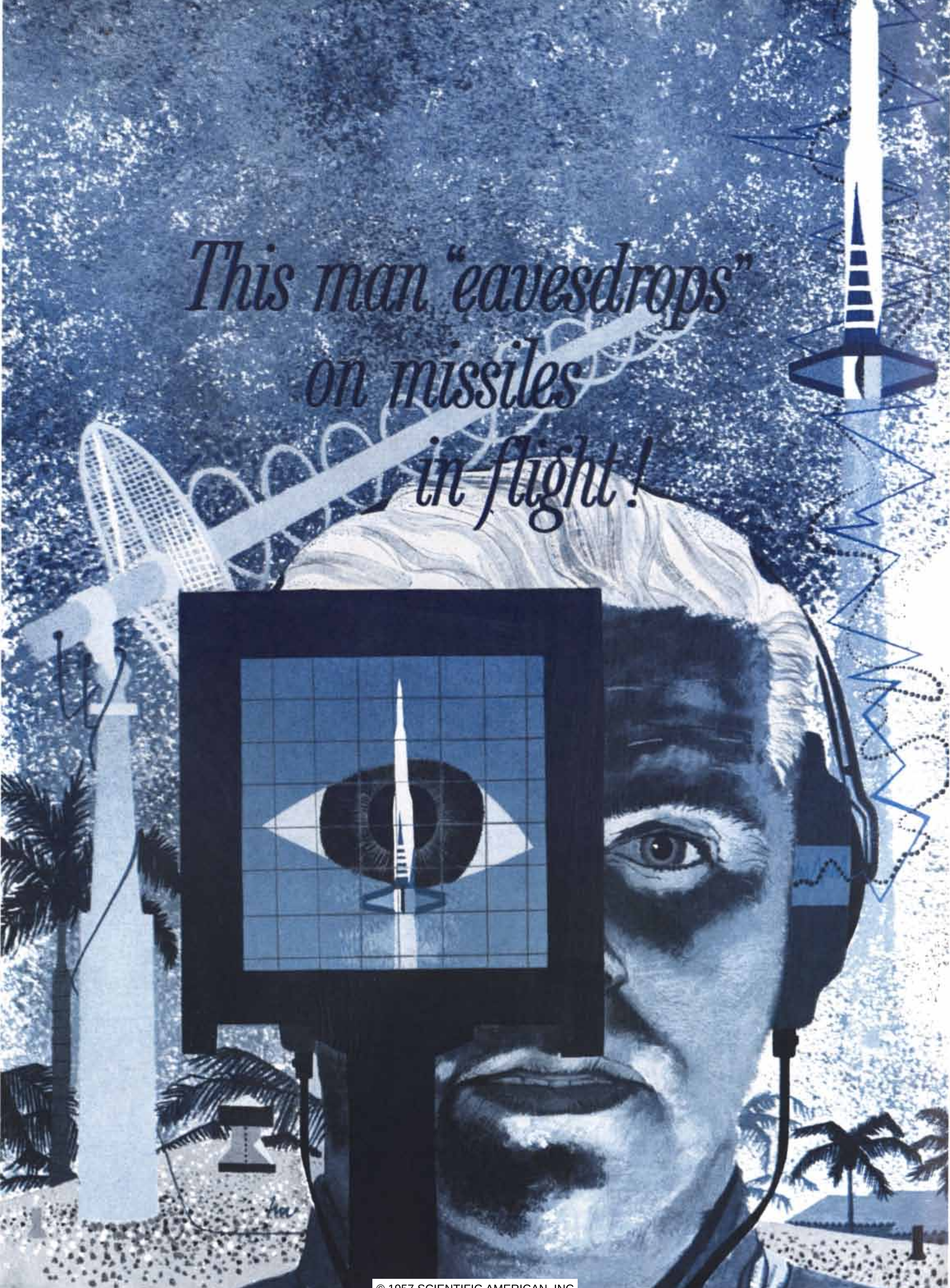
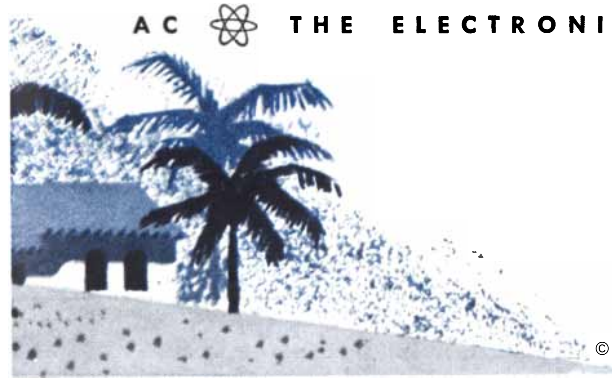
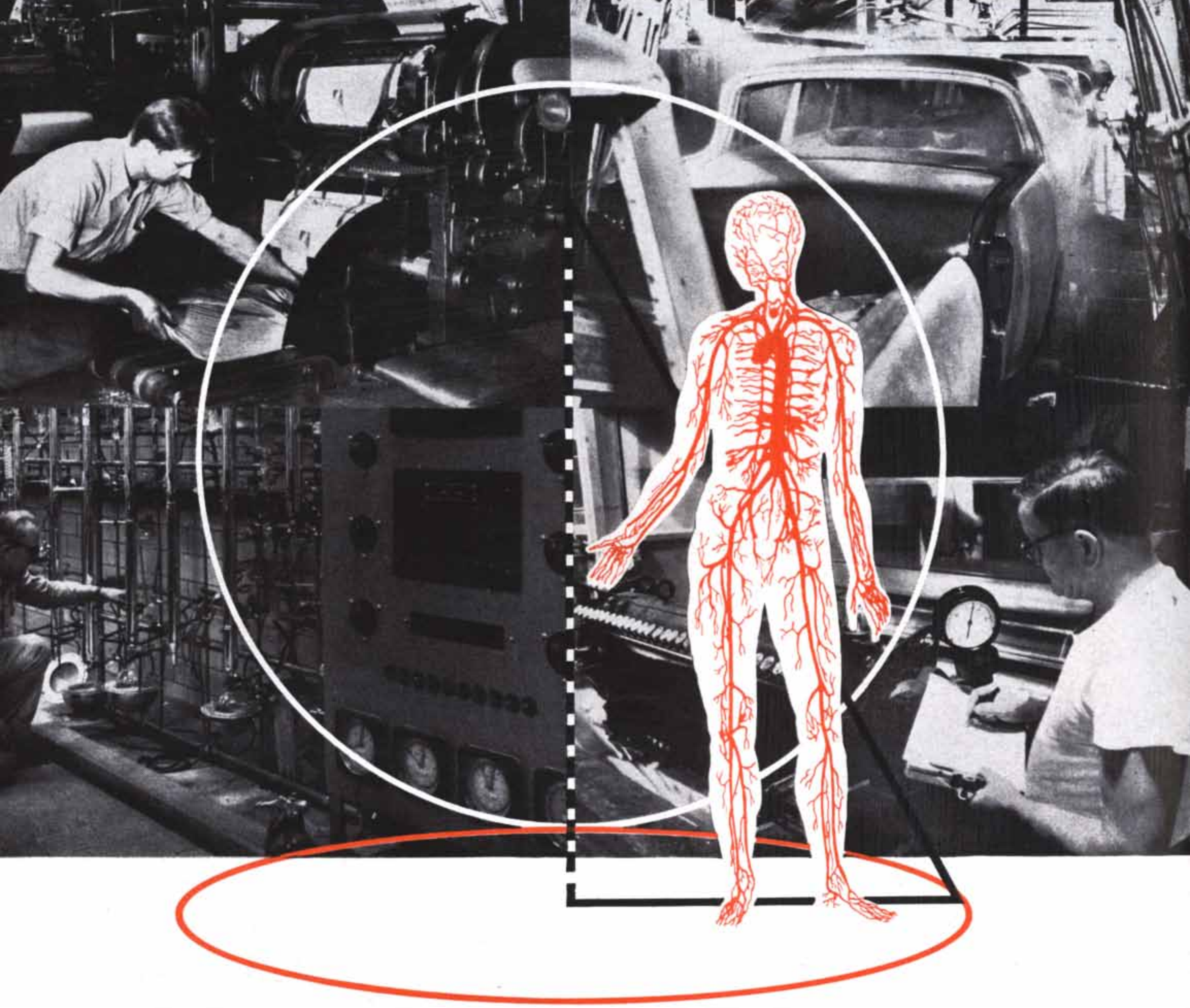

This man "eavesdrops" on missiles in flight!





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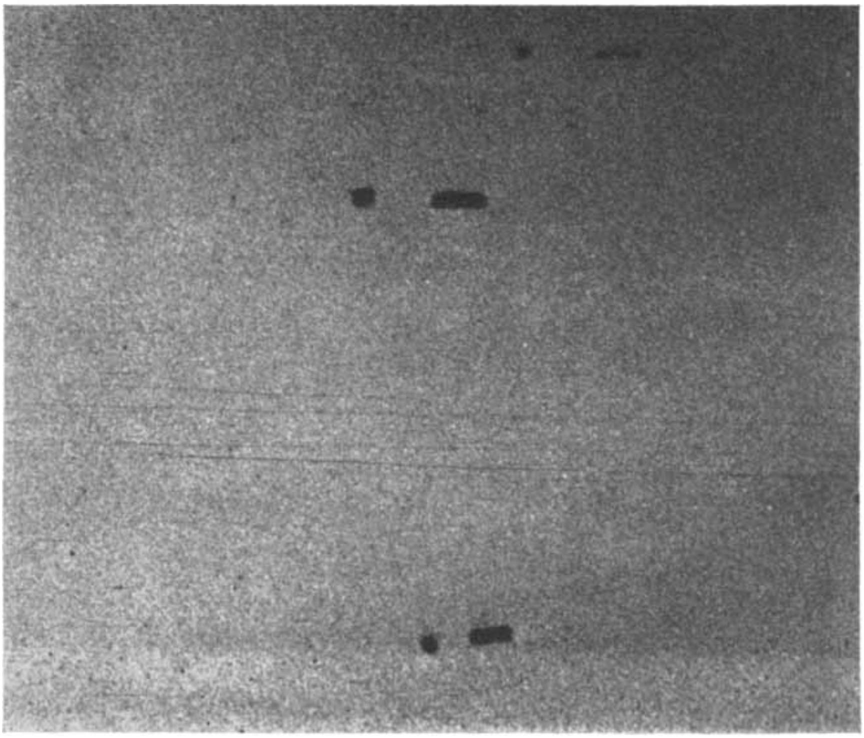
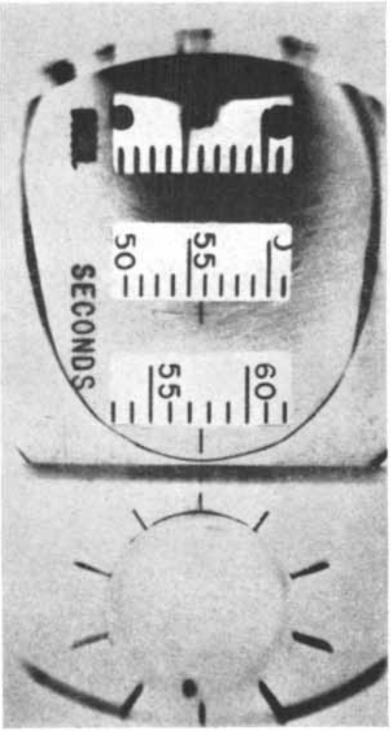
Observations of Satellite I

The artificial satellites are man's first venture into experimental celestial mechanics. An account of how the first satellite's orbit was determined, and how our knowledge of this orbit can be applied

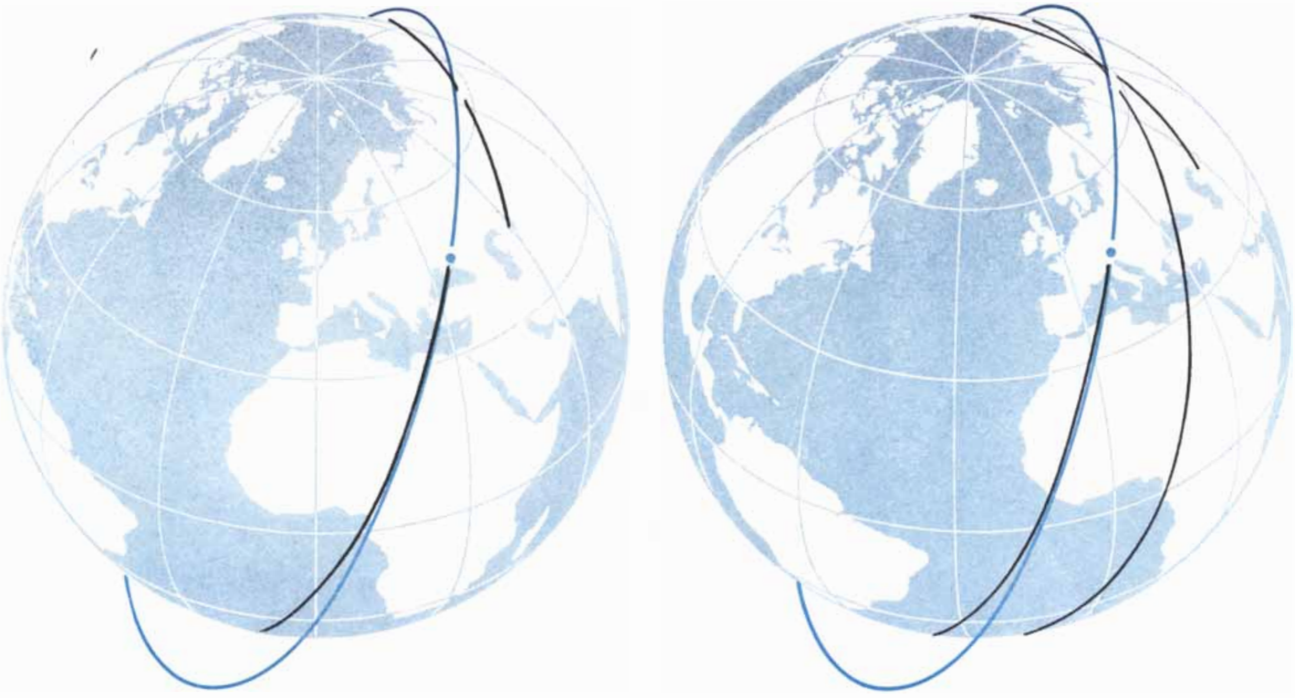
by Fred L. Whipple and J. Allen Hynek

The launching of the first satellites is a triumph of celestial mechanics. With the aid of 20th-century technology man has put into practice, so to speak, the laws of heavenly motion first discovered in the days of Galileo, Johannes Kepler and Isaac Newton. Precise calculations, based upon those laws, were necessary to shoot the satellites into their orbits around the earth. But the man-made heavenly bodies—the U.S.S.R.'s and our own that will follow—are not a mere *tour de force* exhibiting our astronomical and technical sophistication. They are scientific vehicles to probe the far reaches of our atmosphere, the borders of space and, oddly enough, the depths of the earth itself. They are adding to our knowledge of our planet with every trip around the earth. In the first few weeks of their flight, they told





ORBITING ROCKET CASE of the first satellite is seen in the lower part of this photograph as a sharp image (*left*) and as a smeared trail (*right*), formed when the camera was held steady on the fixed stars. Two stars are recorded in the upper pair of images, which are smeared when the camera tracks the satellite and sharp when it tracks the stars. Image trails are "chopped" by a rotating shutter, but the interruptions do not show in this photograph because of overexposure. Clock at right gives time of a specific chop.

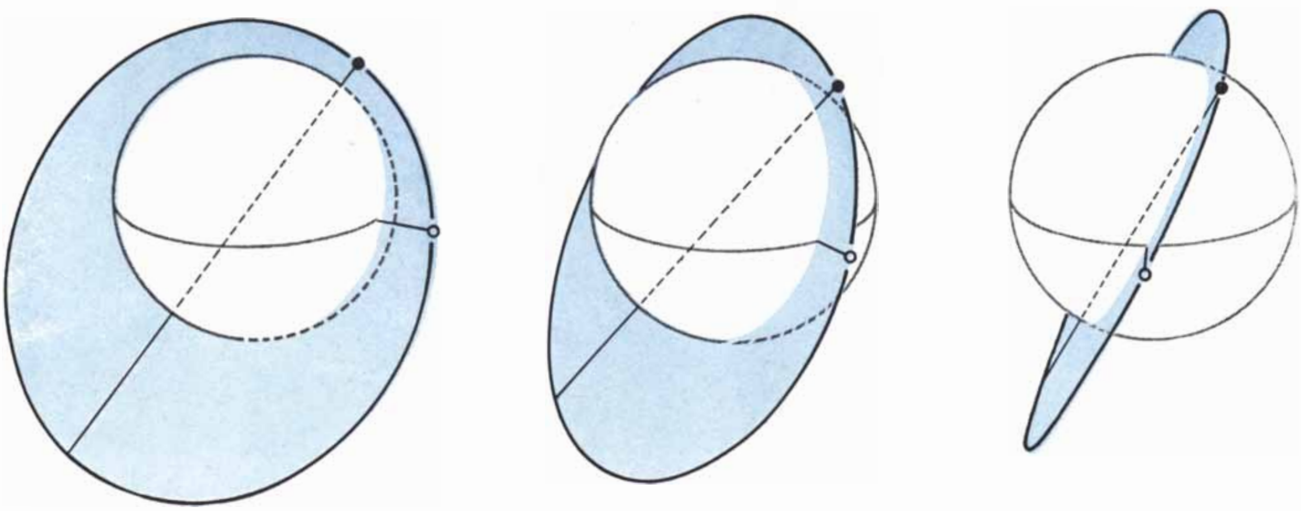


FIRST SATELLITE'S FIRST DAY took it around the earth almost exactly 15 times. These drawings show the orbit in color and its trace on the turning surface of the earth in black. From left to right they depict the completion of the first, second, sixth and

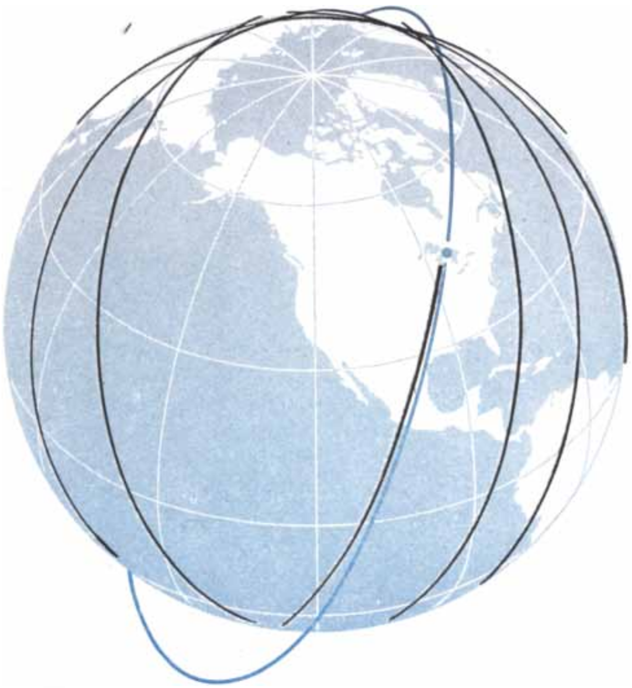
us more about the shape of the earth than 2,000 years of observation of our natural satellite, the moon.

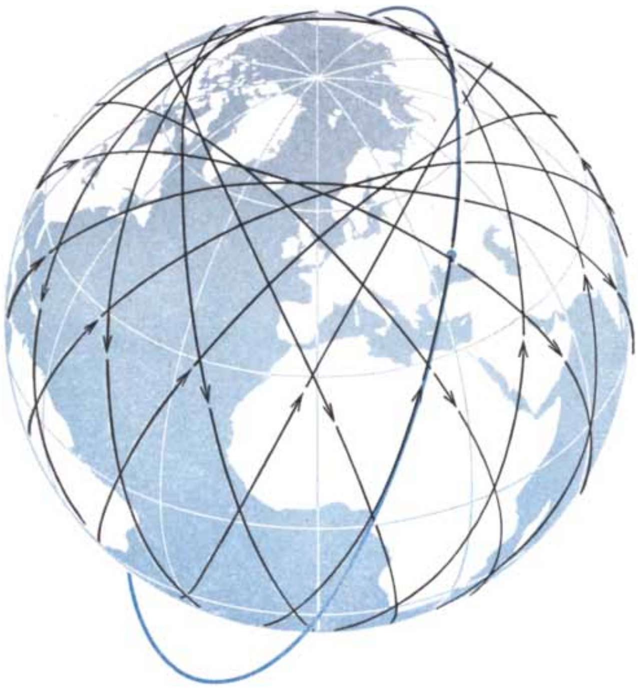
In short, following the satellites and reading the information they have to give is fully as important as launching them successfully. To track these objects and find their exact orbits is a far more difficult task than it may seem. Their positions and motions against the background of stars have to be measured with great precision. Never before have astronomers been asked to track objects moving so rapidly as these artificial moons. Only a world-wide cooperative effort of many observers makes it possible at all. Regrettably, the U.S.S.R. furnished little precise or helpful information about its satellites in the first weeks after they were launched. But thanks to an alert network of International Geophysical Year observers, the orbits were eventually worked out.

Historic moments deserve to be recorded in detail, and we want to put down briefly here how the news of the first satellite came to scientific observers in the U. S. As everyone knows, I.G.Y. committees had set up a world-wide organization for tracking satellites, both by radio and visually. In the U. S. the responsibility for radio tracking was assigned to the Naval Research Laboratory in Washington and for optical tracking to the Smithsonian Institution's Astrophysical Observatory in Cambridge, Mass. A chain of 12 stations called "Minitrack" was organized for radio observation, and the visual observers were organized in "Moonwatch" teams distributed in a picket line around the



MOTIONS OF ORBIT swing its plane in a westerly direction at a rate of three degrees per day, at the same time carrying the perigee and apogee points (nearest and farthest points from the earth's surface) around the orbit at about one half degree per





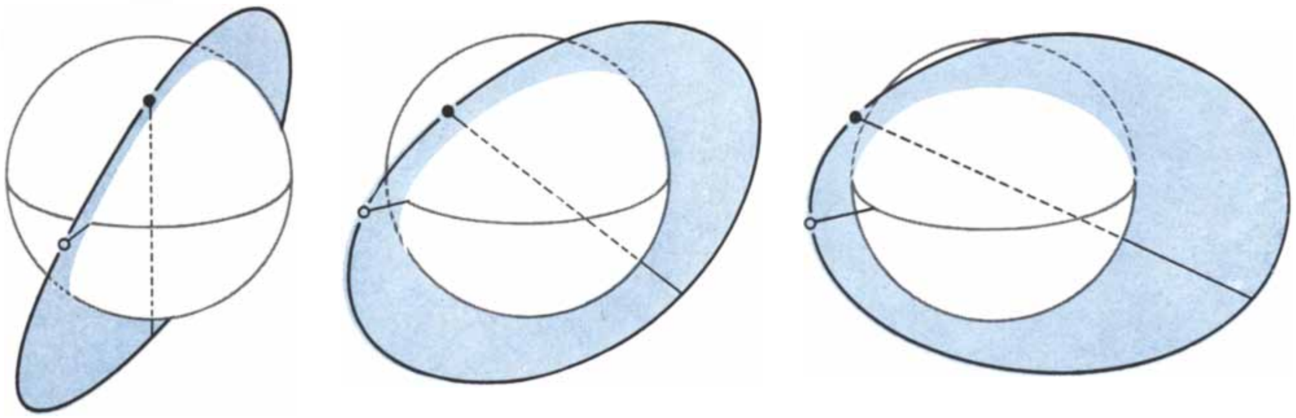
sixteenth revolutions. The launching point is assumed to lie between the Caspian and Aral seas. The drawings are somewhat idealized in that they assume the orbit to be stationary in space and the time for one complete revolution to be precisely 96 minutes.

world. There were 90 Moonwatch groups across the U. S., organized by Leon Campbell and Armand Spitz.

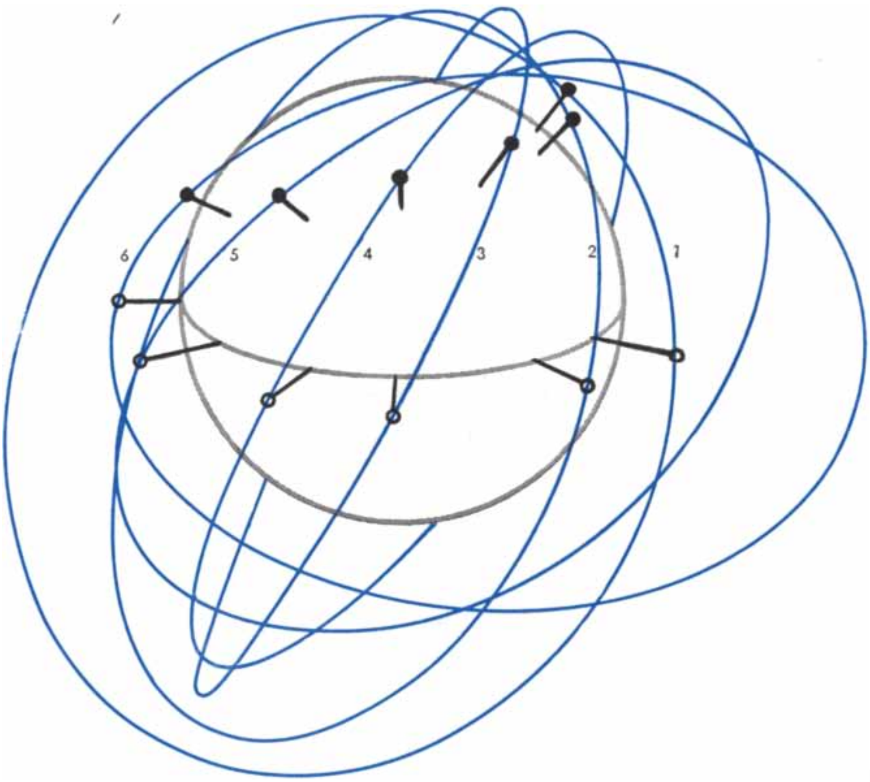
On the evening of October 4, in Washington, the chief I.G.Y. representatives of nearly a dozen participating countries were relaxing at the Soviet Embassy at the end of a week of intensive conferences on the various countries' satellite plans. Richard W. Porter, chairman of the technical panel for the U. S. satellite program, was called to the telephone. He quickly returned and announced to the group: "Gentlemen, our Russian colleagues are to be congratulated. They have successfully launched an earth satellite."

At the Smithsonian Astrophysical Observatory, that Friday evening, almost everybody had left for a quiet weekend (they thought). Only two of us were still in the Observatory. About 7 p.m. the telephone brought us the electrifying, and momentarily paralyzing, news. It was the responsibility of the Observatory to alert immediately more than 2,000 Moonwatch observers around the world. The two people, alone in the empty headquarters, hardly knew how to begin the colossal job. But we were not alone for long. Staff members who had heard the news on the radio at home began to rush back; others were called by telephone; within an hour the lights were blazing all over the building and dozens of workers had begun to send the word to the Moonwatch teams by telephone, telegraph and cable. Working all night, by morning they had reached more than 100 observing teams around the world.

Why the rush? Well, no one knew what Sputnik's orbit or timetable was,



day. The drawings show the orbit at approximately 10-day intervals. Black dot is perigee; open circle is the node, or intersection of the planes of orbit and Equator. Plane of orbit is in color. The flatness of the elliptical path is greatly exaggerated.



ORBIT'S PROGRESS is seen in a composite of the separate positions shown at the bottom of the preceding two pages. The motion is due to the bulge of the earth at the Equator.

ORBITS OF THE FIRST TWO SATELLITES are shown in relation to the earth, approximately to scale. Orbit of first satellite is in black; of second, in color. The perigee heights are both about 150 miles. The apogees or maximum heights are about 550 and 1,000 miles.

nor how short its life might be. The whole sky had to be watched. A satellite would ordinarily be visible only in the dusk of dawn or evening, and we started our messages to observers on the East Coast (where it was still early evening) and worked our way westward. But we had not forgotten that our Soviet colleagues had casually mentioned, on two occasions, that their satellite might carry lights. So Moonwatch kept an all-night vigil that night.

Not until morning did it become clear that Sputnik was following an orbit which would not bring it over the U. S. at dawn or twilight for at least several days. By the following day we had learned enough about the nature of its orbit to see that it should cross Alaska in the early morning, and we at once telephoned the Geophysical Institute there. To our intense pleasure, Gordon Little, the associate director, replied that his group had already seen Sputnik that morning and recorded its position. Actually the bright object seen in Alaska was not the satellite itself but the shell of its last rocket stage. On the evening of the same day, astronomers at the Mount Stromlo Observatory in Australia also saw the rocket, and two minutes later it was spotted by an observer in Sydney. These sightings gave us our first definite picture of the orientation of Sputnik's orbit.

Meanwhile the Naval Research Laboratory in Washington had gone through much the same experience. Sputnik's beep was first picked up in the U. S. at 8:07 p.m. on the evening of October 4. Since the broadcasts were at 20 and 40 megacycles, instead of the 108 megacycles agreed upon in the I.G.Y., the Minitrack stations had to adjust hastily to the lower frequencies with quickly rigged antennas and changes in the receiving gear. Gradually a mass of reports from these stations and radio "hams," supplemented by our few optical observations, gave us the data to begin to compute an orbit. By this time Radio Moscow had contributed a few bits of information: that the orbit was inclined 65 degrees to the Equator, that the satellite made a circuit of the earth in 96.3 minutes and that its maximum altitude, or apogee, was 560 miles. Moscow's predictions of the times at which Sputnik would pass over various cities confirmed our calculations of its orbit.

Precise calculation of a satellite's orbit is essential in the first instance, of course, to tell us where and when to look for it, but the main reason for trying to establish it with very high precision is that the orbit alone, and changes in it, tell us a great deal about the earth. Let us look first at how the orbit is found and then at what it means.

In such an astronomical problem, everything depends on getting accurate fixes of the object's positions in space at precisely measured instants of time. For an object moving across the sky as rapidly as the satellite, an ordinary telescope will not do, mainly because of the tracking problem. The image of the satellite crosses the field of the camera very swiftly (at more than a foot per second in a long-focus instrument), and it may come across the sky from any direction. The conventional big telescope cannot follow it. Accordingly a special satellite-tracking telescope has been designed by James G. Baker and Joseph Nunn. It has been built by the Perkin-Elmer Corporation (constructing the optics) and Boller & Chivens Inc. (the mechanical system).

The telescope has a triaxial mount which allows it to be swung in any direction. To make sure that the film will record a very faint satellite, the camera photographs it in two aspects: as a stopped image and as a trail across the sky. It follows the object to get the point image, and in each cycle it stops momentarily to let the satellite move across the field. Thus each "frame" consists of a double exposure: one showing the satellite as a point of light and the background stars as trails, the other presenting the satellite as a trail against the fixed background of stars [*see photograph on page 37*]. For timing purposes the star trails are chopped by a rapidly rotating shutter, synchronized by a high-precision crystal clock built by the Norrman Company. The timing will generally be accurate to a thousandth of a second. With the satellite moving at 25,000 feet per second, its position in space will be located to within about 25 feet.

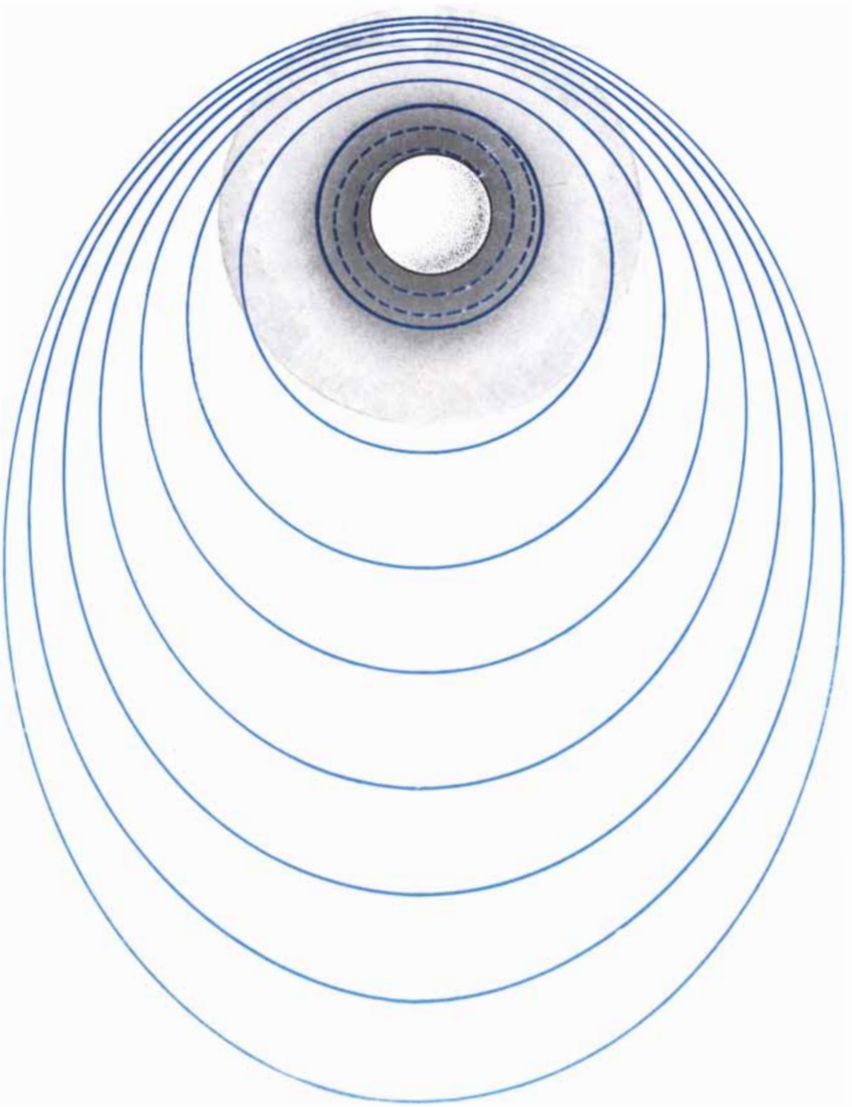
The optical system is a novel design which makes possible the combination of a very wide field (30 degrees) with optimal photographic speed for satellite tracking. The camera has an aperture of 20 inches and a focal length of 20 inches. It is a modified Schmidt camera with three correcting plates.

Twelve of these cameras will be installed in a belt of stations around the world to obtain precise locations of the satellites in time and space. Together with the gauntlet of Moonwatch observers, they will make it possible to measure the vagaries of the satellites' orbits.

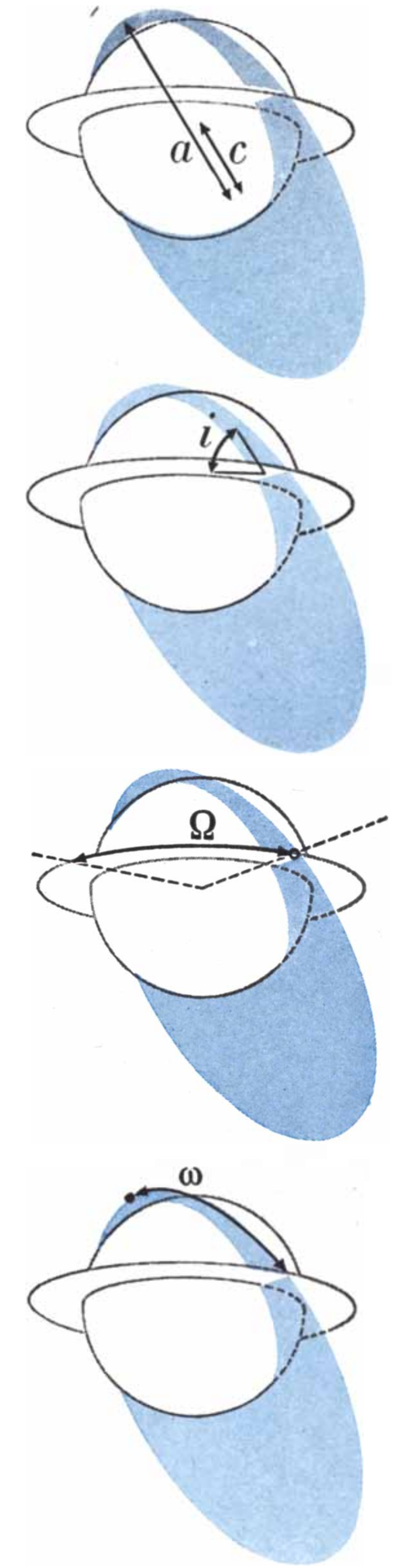
Once we have the location of a satellite's positions at various points in its orbit, the laws of gravitation and Kepler's laws of planetary motion enable us to draw its elliptical orbit. The center of the earth is one focus of the ellipse. Knowing the time the satellite takes to go around the earth and its average velocity, we can compute its mean distance from the center of the earth; or, from information on the mean distance, we can find the average velocity. But Kepler's laws also say that the satellite moves appreciably faster at its closest approach to the earth's center than in the farthest part of its orbit: the speed varies in inverse fashion with the distance from the center. We found that the variation of the first satellite's velocity, shortly after its launching, amounted to some 10 per cent. Thus at perigee (closest to the earth's center) its speed was about 1,800 miles per hour greater than at apogee.

The motion of our natural moon around the earth is disturbed substantially by the sun's gravitational pull on the moon. But the sun's influence on a small artificial satellite close to the earth is negligible. This allows us to see the effects of slight irregularities in the earth's shape on the satellite's orbit. And at the moment an outstanding point of interest is what the satellites are telling us about the slight thickening of our globe's waist due to its rotation: that is, the equatorial bulge.

As a satellite revolves around the earth in its north-south tilted path, the greater gravitational attraction of the



FATE OF A SATELLITE is shown in these exaggerated orbits. As air resistance slows the object down, its maximum height or apogee decreases more rapidly than the perigee. Eventually its orbit becomes circular and further slowing causes it to spiral into the earth.



ELEMENTS OF AN ORBIT fix its position and shape. Letters *a* and *c* (*top*) are the semi-major axis and distance from center to focus respectively. Ratio of *c* to *a* gives eccentricity or flatness. Angle between planes of orbit and Equator is *i*. Large omega is angle between line of nodes and vernal equinox. Small omega (*bottom*) is angle from Equator to perigee on orbit.

earth's bulging mid-section tends to pull it toward the Equator. But the revolving satellite has the property of a gyroscope. When a force attempts to tip the axis of a whirling gyroscope, it reacts by turning the plane of its rotation in the direction at right angles to the force. The result in Sputnik's case is to swing the plane of its orbit around the earth in the westerly direction: in the astronomer's language, the orbit "regresses" toward the west [*see diagrams at bottom of pages 38 and 39*]. The satellite is regressing rapidly—at the rate of 3.1 degrees per day, or three complete turns of its orbit per year. This is much more rapid than the regression of the more distant natural moon, whose orbit makes a full swing only once in 18 years.

The earth's equatorial bulge has another effect on the first satellite's orbit. The orbit turns in its own plane (swinging the perigee around) at the rate of four tenths of a degree per day. Still a third effect of the equatorial bulge is to flatten the satellite's orbit slightly at the north and south ends.

The earth's shape and thickened waistline have fascinated investigators for centuries. In 1736 the French mathematician and astronomer Pierre Louis Moreau de Maupertuis went to northern Lapland to see whether a degree of longitude was shorter there than near the Equator. It was, and Maupertuis thus found the first proof that the Equator bulged and that Newton's laws of gravitation held in the real world. Voltaire sneered:

You who chose 'mid frozen wastes to roam
Proved what Newton showed, who stayed at home.

The man-made satellites now roaming the frozen wastes of our planet's border are again confirming what Newton showed, but with an elegance which would have impressed even Voltaire.

Future satellites, launched to greater heights and tracked by more highly organized networks of stations, will measure with great exactitude the earth's shape, size and geography. By tracing the distribution of the earth's mass, they will also chart its internal structure.

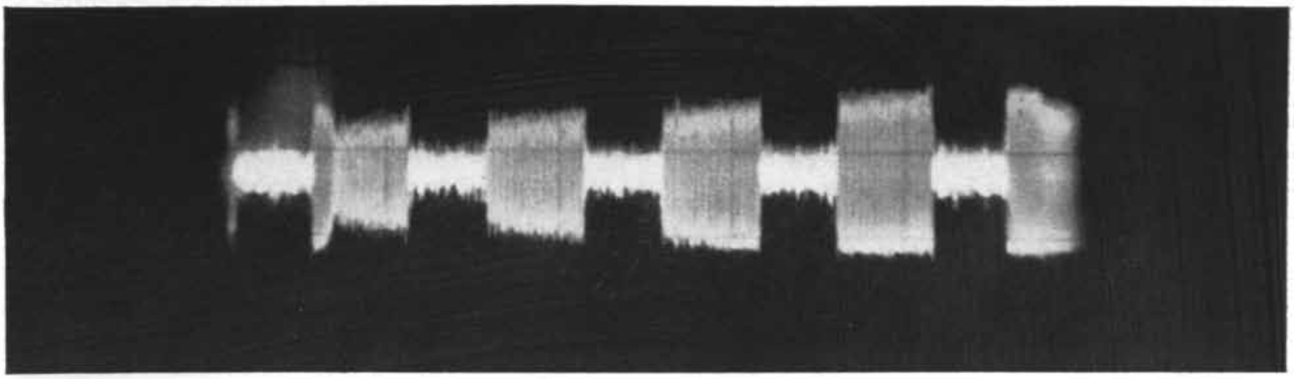
Meanwhile, what else are the satellites telling us? They are giving us direct measurements of the air density and temperature of our upper atmosphere out to 150 miles or more. That air resistance is still appreciable at 150 miles is shown by the fact that the orbit of Sputnik I began to spiral slowly downward toward the earth immediately after it was launched. At the time of writing, we estimate that Sputnik I will plunge into the denser air and burn up around December 11. Further, the deflection of the satellites' radio signals by the ionosphere below them is giving us measurements of the density of that electrified blanket. The satellites are bringing in information about ultraviolet and other radiations from the sun which do not penetrate to the ground, about cosmic rays, about meteors and doubtless about other matters that the Soviet scientists have not yet specified.

The satellites have also been a sharp prod to techniques in astronomy. They compress centuries of celestial motion into a few weeks. From the standpoint of providing information, each week of Sputnik I corresponded to eight years of the motion of the moon and a dozen centuries of Jupiter's motion around the sun. The new problems in observation are generating new techniques in optics, in radio tracking, in world-wide timekeeping and in rapid computation of orbits.

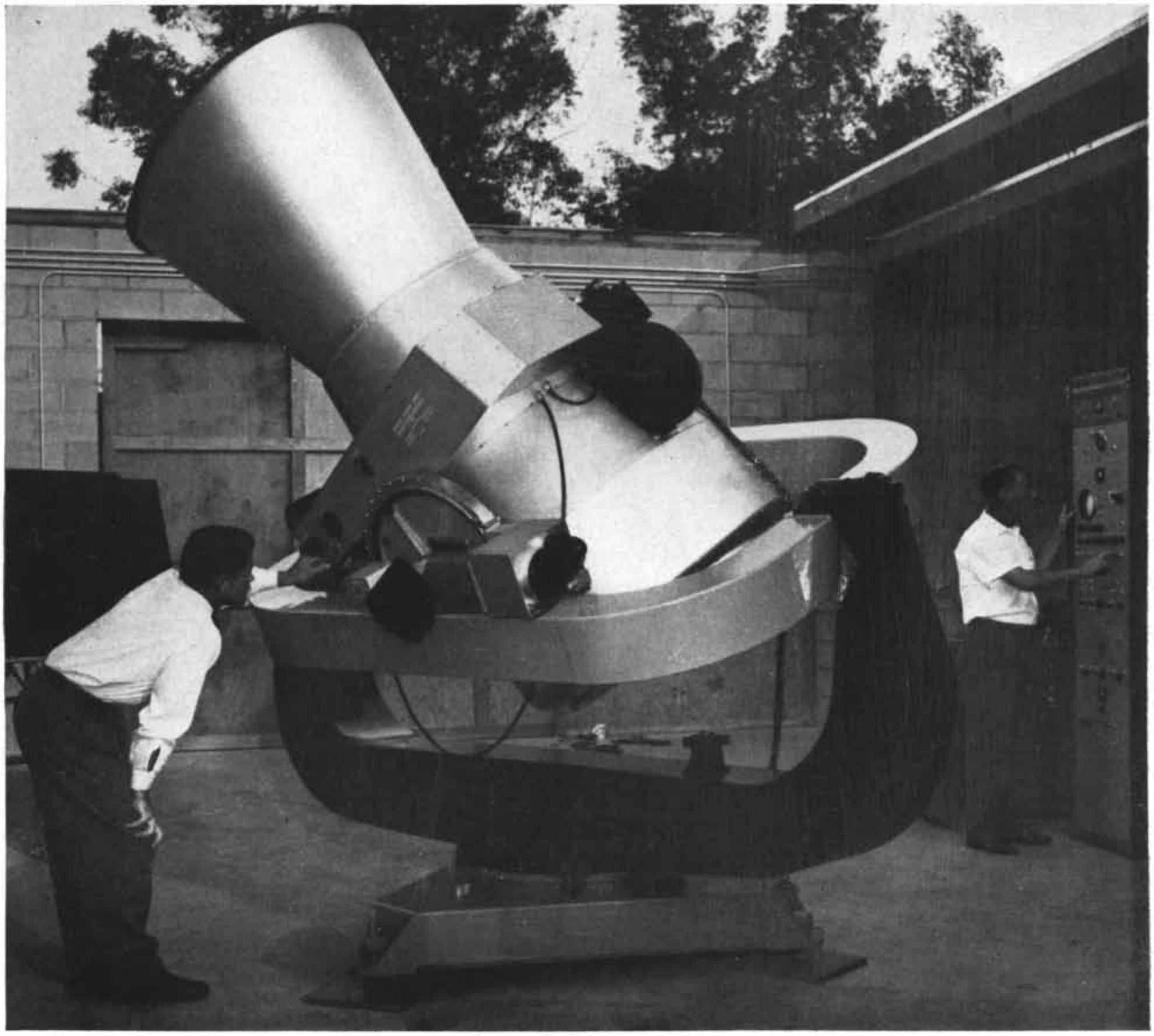
But above all, the first successful satellites have proved that "the thing can be done." They have turned all eyes skyward. And the curtain has just barely risen on this fresh scene of science. We can expect rapid developments. Adapting an astronomical convention based on the naming of comets, we have suggested a system of naming artificial satellites which the U. S. National Committee of the I.G.Y. has approved. Sputniks I and II, under this system, are called 1957 Alpha and 1957 Beta. Very likely 1957 Gamma will not be far behind. Scientists can begin to lay more elaborate plans for their successors in 1958 and the years to follow.

Astronomers, naturally, are looking forward not primarily to space travel but to setting up outposts for scientific observations—astronomical observatories in space, far above our murky and tremulous atmosphere. The new astronomy will call for a whole new technology: permanent or at least long-lived power sources, platform stabilizers, television eyes peering outward as well as downward, new methods of analyzing unaccustomed radiations (such as the far ultraviolet and X-rays), self-repairing electronic and radio systems, perhaps even repair robots.

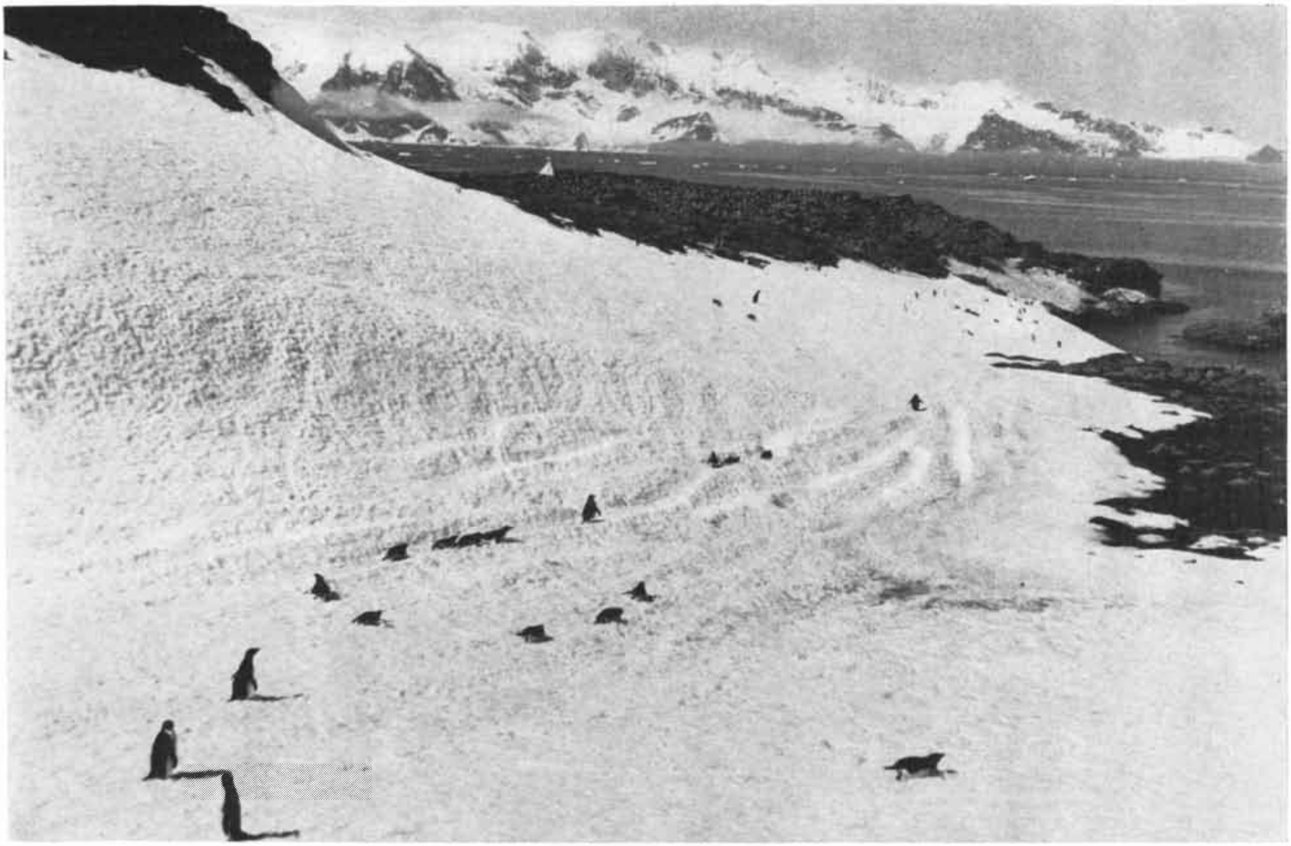
In his millennia of looking at the stars, man has never faced so exciting a challenge as the year 1957 has suddenly thrust upon him.



BEEPING RADIO SIGNAL from the first satellite was recorded on an oscilloscope of the Stanford Research Institute. This trace shows the 40-megacycle signal over a period of two seconds. The signal strength provides information on the state of the ionosphere.



SATELLITE-TRACKING CAMERA, which was designed especially for this purpose, is photographed at the plant of Boller & Chivens Inc. in South Pasadena, Calif. It is a wide-angle Schmidt telescope. Photograph on page 37 was made with this instrument.



ADELIE PENGUINS ascend to their rookery on the bare ground near the top of this photograph. The small white triangle in this area is Sladen's tent. The rookery is on Signy Island in the South Orkney Islands, which are 400 miles from the Antarctic mainland.

NESTING ADELIE PENGUIN at left is a male which is just being relieved at the nest by its mate. The male has been at the nest without food for 40 days, during which time it has lost 40 per cent of its body weight. The female wears an aluminum band.

PENGUINS

Although they are associated with the Antarctic, it is not widely realized how well they are adapted to this formidable environment. For example, a penguin can fast 40 days in order to raise its young

by William J. L. Sladen

My first introduction to penguins in their natural haunts came on a frigid Antarctic morning 10 years ago. The royal research ship *John Biscoe* was pushing at reduced speed through ice-infested water near the South Shetland Islands off Antarctica. As day dawned, the desolate stillness of the icy ocean was broken by a sudden chatter of strange cries. We found ourselves in the midst of a crowd of the charming black and white birds which are so familiar in photographs but which few people have ever seen on their home grounds. All around us penguins were "flying" through the water, leaping into the air like little porpoises and shouting to one another with their melodious call—*aark, aark.* It was a never-to-be-forgotten experience.

The cold-loving penguins are difficult to preserve in captivity, and very few zoos have ever been able to breed them or to keep them in large numbers. To see how penguins really live, you have to study them in the wild. When I went to the Antarctic in 1947, it was in part expressly for the purpose of investigating penguins in their habitats. I signed on as a medical officer with an expedition of the British Falkland Islands Dependencies Survey (what we call F.I.D.S.), which since 1944 has been carrying out continuing research in the Antarctic from permanent bases. Since all the men are carefully picked for health and ability to endure Antarctic life, there was not too much for a medical officer to do, and I had ample opportunity to become acquainted with the penguins.

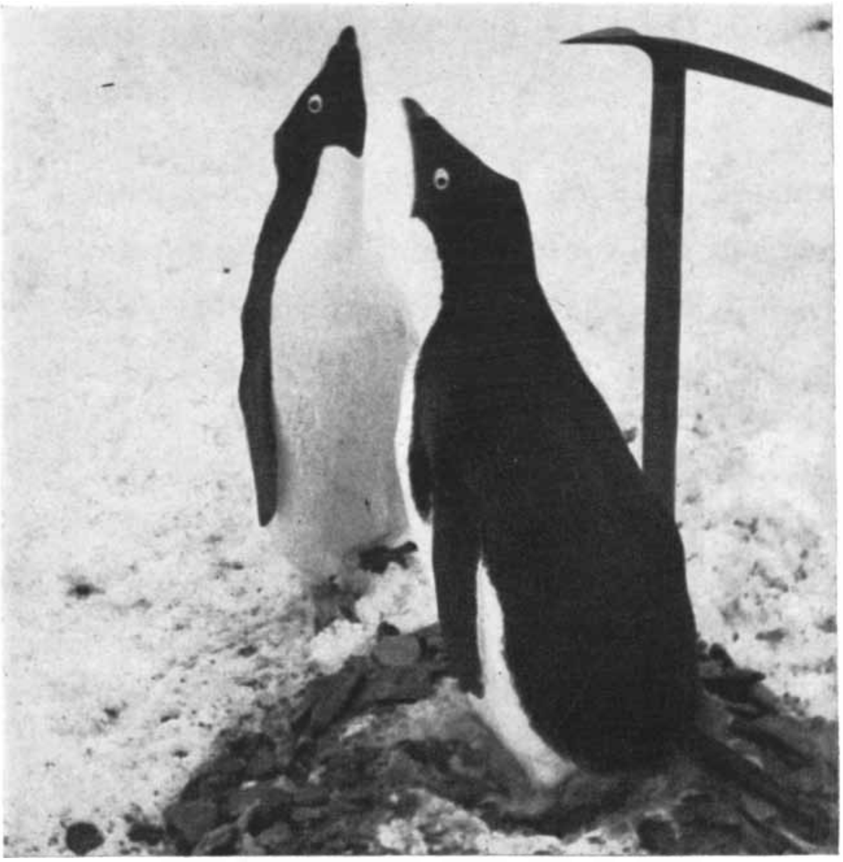
Penguins are peculiar to the Southern Hemisphere: their white-breasted northern counterparts in the Arctic are not penguins but auks and puffins. The penguins almost certainly originated in the Antarctic region, for fossil penguins found in that area of the world go back to early in the Tertiary Period (*i.e.*, some 50 million years ago). But today they are not confined, as the conventional pictures may suggest, to the icy polar wastes. Following cold ocean currents, they have spread to the coasts of New Zealand, Australia, South Africa and up the west coast of South America. Indeed, the chilly Humboldt Current of South America has taken them as far as the Galápagos Islands just south of the Equator. The wide distribution of the penguins has brought diversification of the species.

The species differ in head coloring and other markings, but all have the typical white breast and black back. This may well serve as camouflage against their enemies (chiefly the leopard seal), for in the water they blend into the background of light from below and into the darkness of the water from above. The penguin's body is beautifully adapted to its life in cold waters. Unlike other birds, it is almost completely covered with feathers. Its dense coat of short, stiff feathers, overlapping almost like scales, gives it excellent insulation against heat loss. The only piece of bare skin on its whole body is a very narrow strip on its abdomen which widens to about an inch and a half when the bird incubates its eggs and becomes grown over with feathers again after the eggs are hatched. Penguins cannot fly: their wings are reduced to flippers for swimming. The streamlined body can reach high speed in the water—perhaps as high as 30 miles per hour.

There are 17 species of penguin, classified in six families. They include the Humboldt species, the Galápagos species, other species in South America, South Africa, New Zealand and Australia. But by far the largest in population are the species that breed in the Antarctic or sub-Antarctic. Among these are the king and emperor penguins (some four feet tall) and the smaller chinstrap and Adélie species. The chinstrap breeds in vast colonies, sometimes amounting to a million birds, on the South Shetland Islands. But even more numerous is the Adélie, probably the best known of all the penguins and famed as "the clown of the Antarctic."

It was the Adélie that I set out to study. To follow its fascinating life history I began by marking a large number of the birds. Penguins lend themselves admirably to this method of study; they are, among other things, easy to catch. The practice of banding birds, in fact, started with penguins as one of the first subjects. In 1908 L. Gain of the French Antarctic Expedition tied green celluloid bands on a number of penguins and so discovered that they came back to the same breeding area the following spring. In recent years F.I.D.S. has banded birds with numbers to identify individuals. In our study, which extended over two Antarctic seasons, we banded 338 birds, marked 1,360 others with paint and dissected many. One of the reasons for the dissections was to identify the sex of the birds, because it is very hard to tell a male from a female by inspection.

The Adélie penguin spends the Antarctic winter at sea hunting its food—the small shrimp called krill, which is also the main diet of whales. In early spring the Adélie starts a long trek over the still-frozen sea to its breeding ground on the Antarctic land coast. It sometimes has to walk as far as 60 miles over the sea ice to its rookery. Since the rook-



MALE AND FEMALE ADELIE PENGUINS perform the "mutual" display with which they greet each other at the nest. This display occurs when one bird comes to relieve the other.

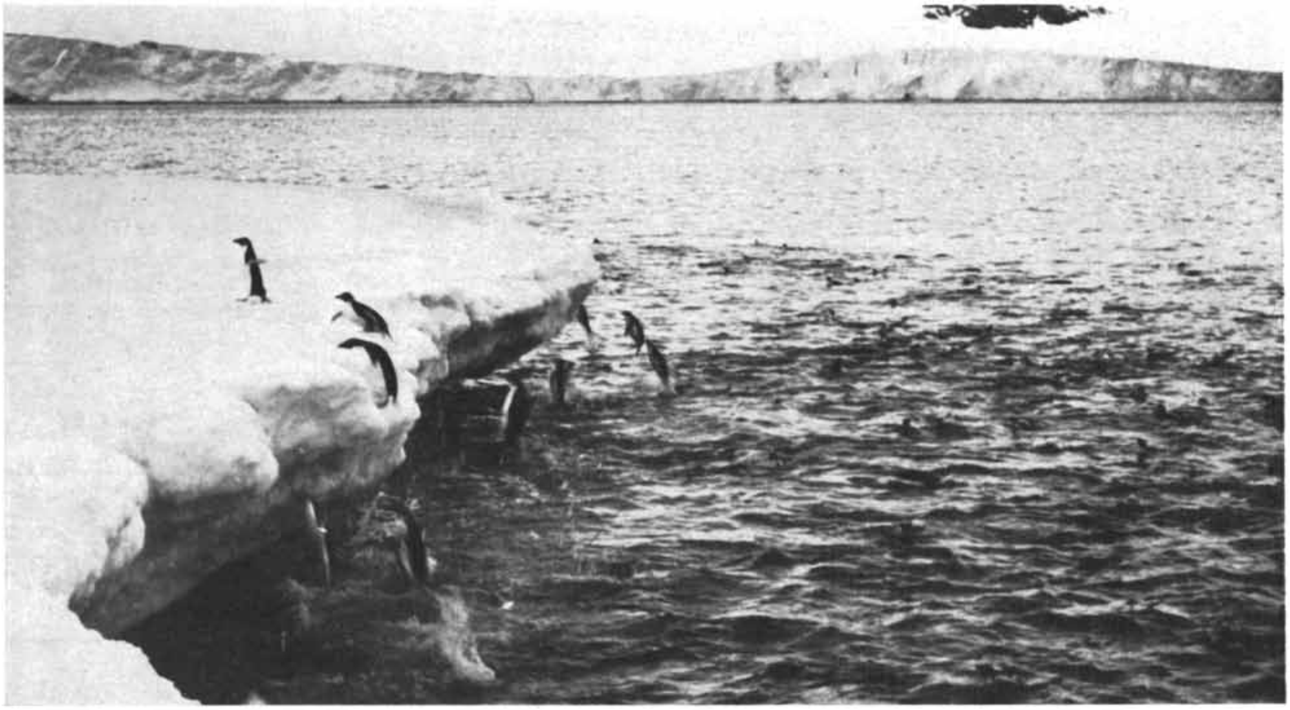
ONE-WEEK-OLD ADELIE PENGUIN CHICKS are the two fluffy balls at lower left. Their heads are beneath the parent, for warmth; their rear ends are out of the nest, for hygiene.

ery is too far from open water for the penguin to walk back regularly for food, the bird is prepared for a long fast. It is plump with a reserve supply of fat: the male Adélie weighs about 13 pounds, the female about 11 pounds.

On arriving at the breeding ground, the birds take up stations at sites where they will build their nests. In many cases the male goes without hesitation to a particular site and stays there. To establish his territorial claim, and attract a female, he performs what is called the "ecstatic" display. The bird stretches his neck, cocks his bill toward the sky, slowly waves his flippers back and forth and finally lets forth a raucous caw. Often a female comes running. But the male may not need to call for a mate. The partner with whom he mated in the preceding season may meet him at the same site. We found that Adélie penguins which had been banded with individual numbers by F.I.D.S. workers came back to the same nest sites year after year and were, on the whole, faithful to their mates of the preceding season.

The partners frequently perform a mutual display, facing each other and waving their stretched necks and heads in unison. After the snow has thawed a little, the male and female begin to build a nest of stones. Popular accounts have it that the male drops a stone at the feet of the female, and if the female accepts this courtship token, the bond between the two is established. My observations failed to substantiate this charming story. One of the pair may collect stones and drop them near its mate, which constructs the nest. The purpose of the nest, in part, is to keep the eggs above water when snow falls on the nest and melts. It has to be built up from time to time with fresh supplies of stones, because penguins have a habit of stealing stones from one another's nests.

By early November, some three weeks after their arrival at the rookery, the female lays two bluish-white eggs, each weighing about three and a half ounces. The male then takes charge of the nest and eggs, and the female goes to sea to break her fast. About two weeks later she returns to the nest, and the pair now perform a ceremonious "changing of the guard." As they wave their stretched heads at each other again and again, the male rises stiffly from the eggs and the female takes his place. He then repairs the nest and waddles off to the sea for his turn to feed. He comes back in two weeks and relieves the female to give her another chance to go for food. When



ADELIE PENGUINS LEAP OUT OF THE WATER to a ledge of ice. The top of the ledge is some seven feet above the water. The penguin is an excellent swimmer. Its food consists of the small, shrimplike creatures called krill, which are also eaten by whales.

she returns, she brings food for the chicks, because by now, after an incubation period of about 35 days, the eggs are hatching. She feeds the chicks with semidigested food which she regurgitates from her stomach. During their growth period the youngsters get fed about every two days, and a chick can take up to one and a half pounds of food at a single meal! The parents take turns going for food and standing guard over the chicks.

At the age of about four weeks the chicks leave the nest. Groups of about 100 chicks then gather together, mainly for protection against the predatory skua. The chicks still have to be fed by their parents, and you may well ask: How do the parents pick out their own chicks from a mob of 100? The authorities used to think that the parents did not recognize their own but simply fed chicks on a first come, first served basis. However, I discovered by watching marked birds that the parents do feed just their own offspring. If the food-bearing parent does not find its chicks, it stretches its neck and begins to caw noisily. Its offspring, even when asleep, promptly wake up and run to be fed.

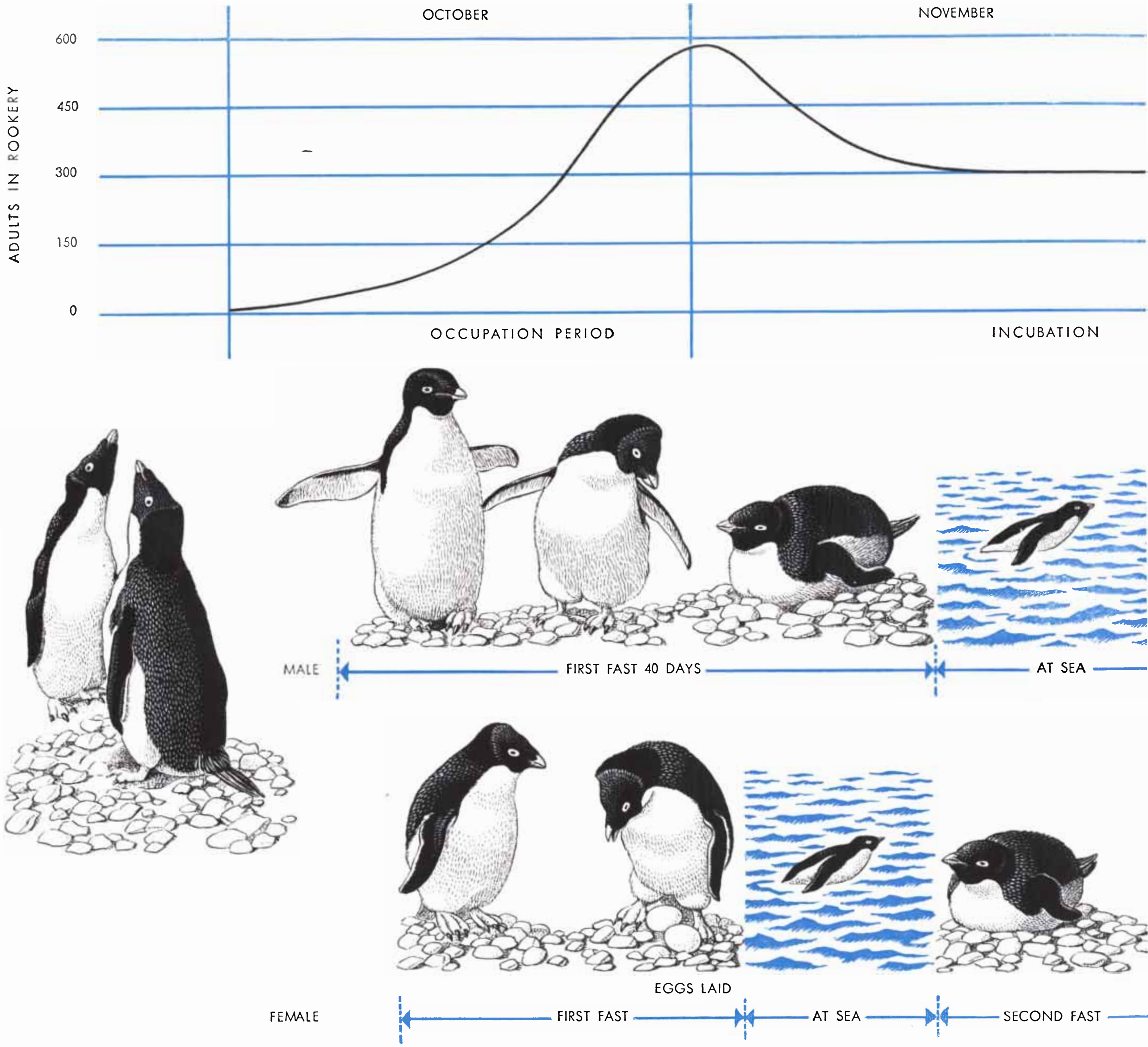
This matter of recognition is one of the most fascinating questions about penguins. Other workers have confirmed that parents and their chicks recognize each other, and it is also plain that the adult birds must have some means of identifying their own mates, even after a winter's separation. Because males and females are indistinguishable by superficial markings, investigators in the past have wondered whether penguins can tell each others' sex, and some even suggested that the birds might have to decide the question by trials at copulation! But close observation of marked birds has now established that penguins readily identify one another, by sound, by performance in the mutual display and also by appearance. Adélie penguins have a strong propensity for forming and maintaining partnerships under all circumstances. When a bird arrives at a nest site before its mate of the previous season, it may start "keeping company" with a new partner. However, when the original mate arrives, it nearly always ousts the usurper.

The penguin's ability to locate the same nest site year after year is another remarkable thing. In the spring the Adélie waddle many miles to their destination over rough sea-ice in which these short-statured birds, only a foot and a half high, cannot see much more than a few yards ahead. And when they arrive at the rookery, they go straight to the spot where they nested the preceding year, even when it is covered with a foot of snow. How they can recognize their own site is difficult to imagine.

The family ties of penguins are very strong. After the chicks have left the nest and spent several weeks with other chicks (called the "crèche" stage), each returns at the age of eight or nine weeks to its parents' nest territory. Not until it has moulted its down and acquired its juvenile plumage do the parents finally abandon the chick. At that stage the young penguins move in groups to the water's edge, stand around exercising their flippers (as other young birds exercise their wings) and finally venture into the sea. Some observers have reported that the parents give their chicks swimming lessons, but this is not true of the Adélie: they learn to swim by themselves. Their first, tumbling attempts to leap porpoise-like out of the water are very amusing to see.

No other vertebrate animal breeds as deep in the Antarctic as the penguins. The species that goes closest to the South Pole is the emperor penguin. Forty-six years ago Edward Adrian Wilson, chief scientist of the Scott expeditions (who perished the following year after reaching the South Pole), reported that the emperor penguin was "eccentric to a degree rarely met with even in ornithology." He found that it bred on the Antarctic continent in winter, that it made no nest, that it carried its eggs and its chicks around on its feet and that it migrated on ice floes. In recent years Bernard Stonehouse of F.I.D.S. and Jean Prévost of the French Polar Expedition, working on opposite sides of the Antarctic, have studied these remarkable birds closely, living with them on their breeding grounds in midwinter. The emperors arrive at their breeding quarters around the middle of March, at the beginning of the Antarctic winter. It takes two months to incubate the eggs, and the male does all the sitting himself, while the female feeds at sea. At hatching time the female returns, finds her mate (though there is no nest) and proceeds to feed the chicks. The family maintains its unity in spite of long separation in an icy wilderness without any fixed home. The dedication and endurance of the father also are quite remarkable. He goes without food through the cold Antarctic winter for a period of about three and a half months.

Only by marking the birds was it possible to establish these extraordinary facts. By the same device L. E. Richdale has learned a great deal about penguins in an 18-year study of the yellow-eyed species of New Zealand. He concentrated on a colony which breeds in woodland, using nests made of sticks, along the coast near Dunedin. Marking the birds year after year, he attained the enviable position of knowing the ages and histories of most of the members of his colony. Richdale is the only investigator who can speak with au-



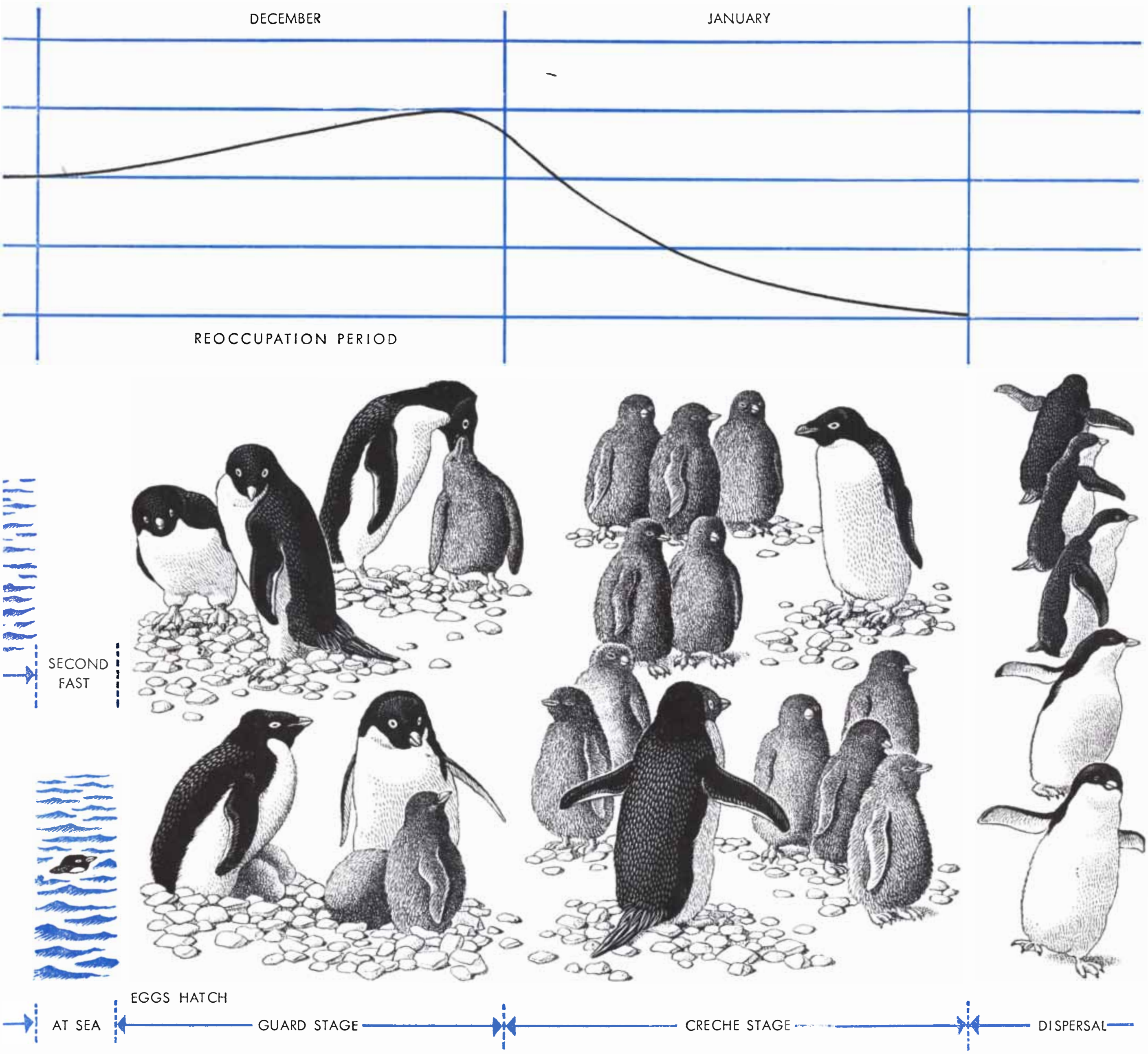
MAIN EVENTS IN THE BREEDING SEASON of an Adélie penguin rookery are outlined. During the "occupation period" the population builds up. Males and females remain together until the eggs are laid. Then the female feeds at sea, leaving the male to

thority on the life span of penguins. He found that his species began to breed at the age of two and lived for 20 years or more: one bird that he banded in 1936 when it was at least two years old was still alive in 1954. Richdale has systematic data on the birth and death rates, fertility, behavior, movements and divorce rates of his penguins.

Stimulated by his work, members of the F.I.D.S. and the Australian Antarctic Research Expedition are carrying out long-range bird-banding projects which should answer many biological questions about which ornithologists and ecologists have been theorizing for years.

Meanwhile progress is being made in studying penguins under laboratory conditions. Penguins are a popular exhibit in zoos, but few people realize that these specimens are living under conditions completely unnatural to them and are very difficult to keep. Fewer than 25 per cent of penguins taken from their wild environment survive longer than a month or two. Besides the hazards inherent in the change of climate and other alterations of their surroundings, penguins are very susceptible to infection, particularly the fungus infection called aspergillosis.

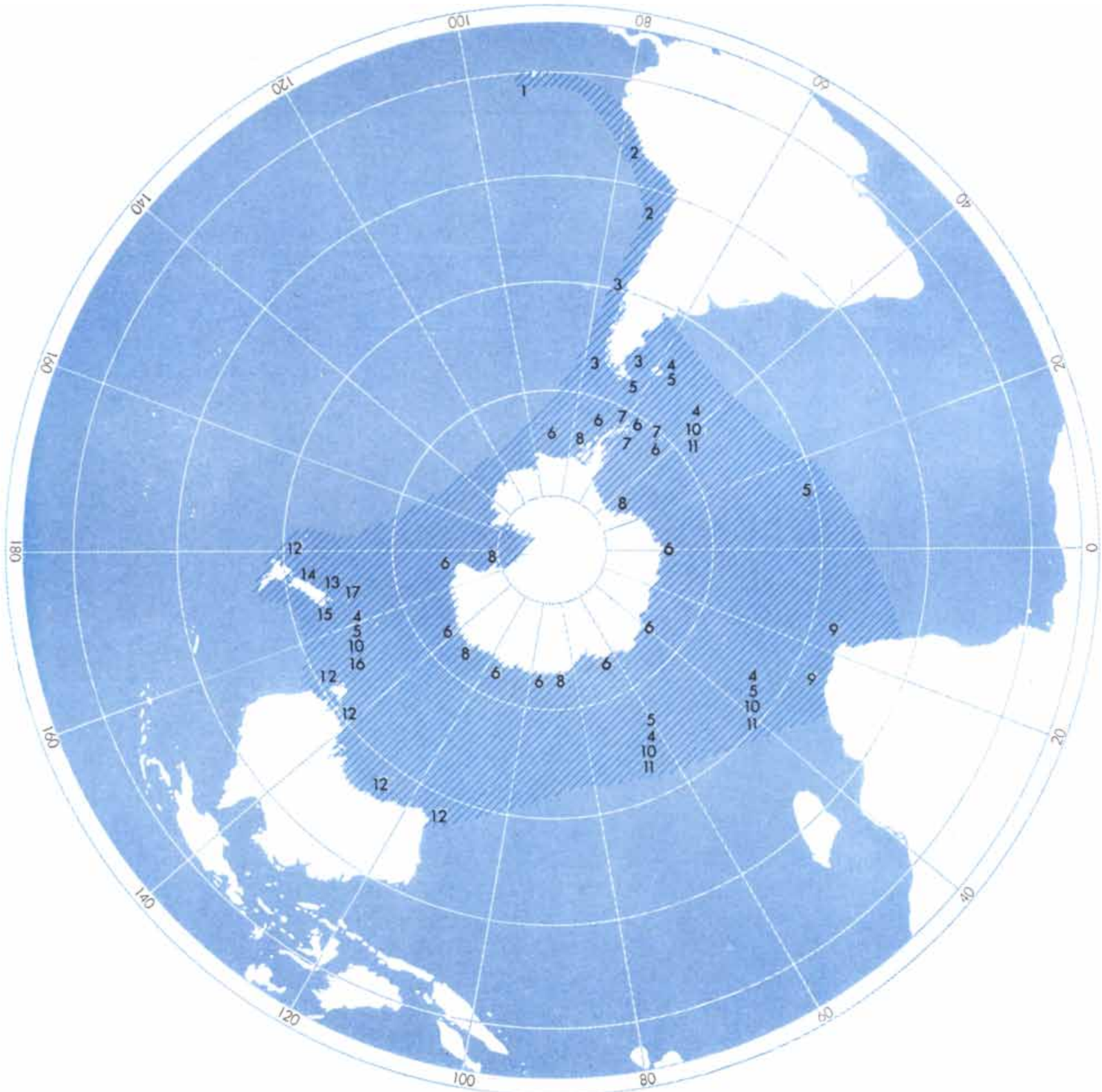
The zoos that have had some success in breeding cold-climate penguins are those in Edinburgh, Vancouver and London, where the outdoor climate is not too unfavorable. In recent years several other zoos have been able to keep,



continue his fast. When the female returns, the male feeds at sea. The newly hatched chicks are guarded by one or the other of the parents and fed by them alternately. When the chicks are about four weeks old, they herd together in "crèches." Finally they disperse.

but not breed, cold-loving penguins by building special refrigerated rooms for them. In the first such refuge, at the National Zoological Park in Washington, two emperor penguins brought back from the Antarctic by Admiral Richard E. Byrd lived for several years. Probably the best exhibit of penguins behind glass in the world today is the one in the Bronx Zoo. There penguins of the emperor, king, chinstrap and other species disport themselves in a cooled tank to the delight of thousands of visitors.

My wife and I, unable to forego the charm of penguins, have been keeping a group of Humboldt penguins at the Johns Hopkins University. Coming from a comparatively warm climate, Humboldts endure captivity better than the Antarctic or sub-Antarctic species. With the enthusiastic encouragement and cooperation of Curt P. Richter and Horsley Gantt of the biological laboratories at Johns Hopkins, we have now kept our penguins for nearly 18 months, and they have settled down in their strange quarters surprisingly well. They are certainly most unusual laboratory animals. The Humboldt penguin's displays are very like those of the Adélie, but more spectacular and noisier. In the "ecstatic" display, which announces its territorial claim and summons a mate, it raises its head and neck to the sky, gives a few soft *kuk-kuk-kuks*, takes a deep breath and emits a long, wailing bray, usually repeated three times. (In the Falkland Islands and South Africa a popular name for the Humboldt's local braying relatives is "jackass.") The first time one of our penguins brayed, while they were



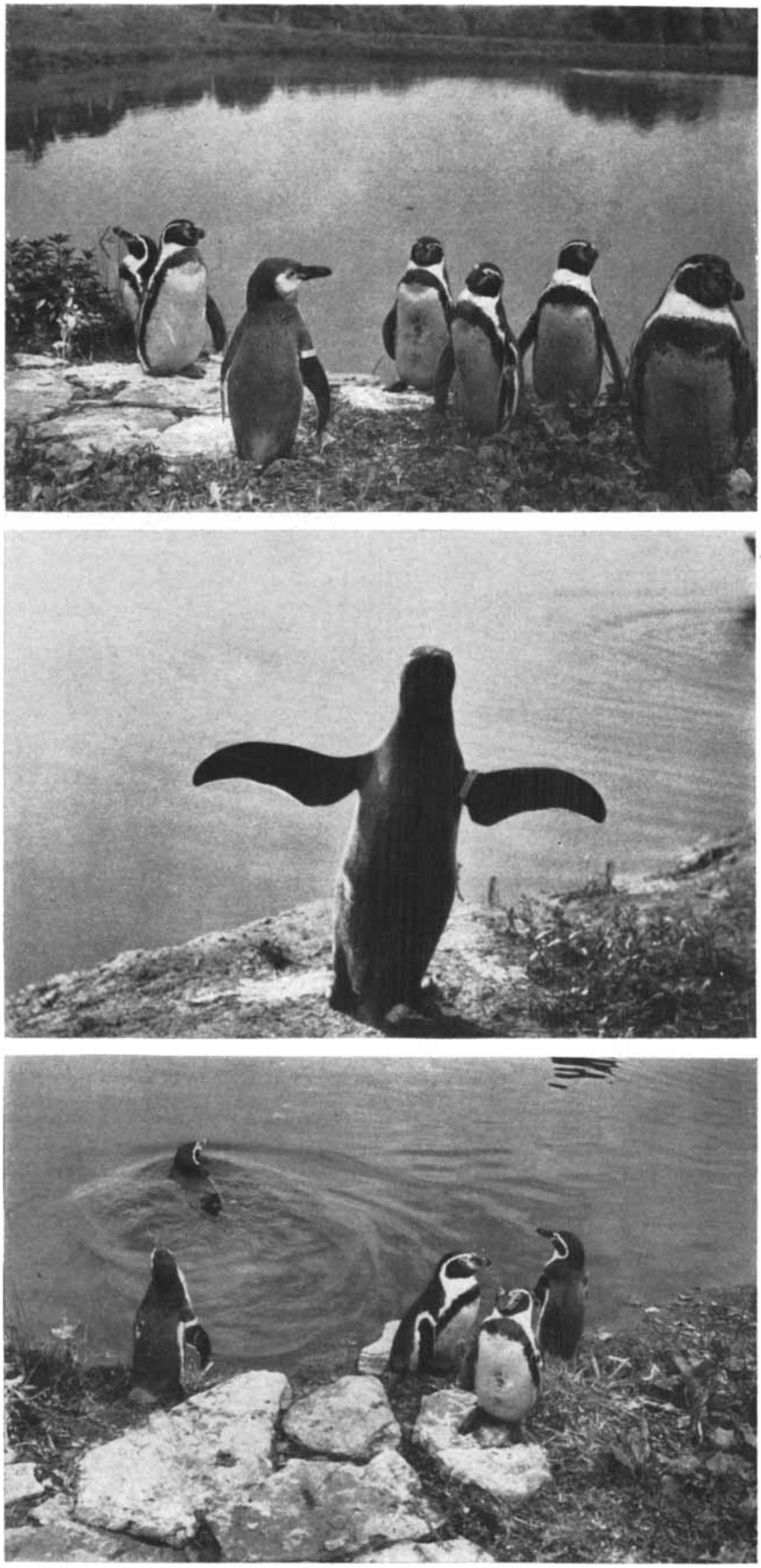
DISTRIBUTION OF PENGUINS (*hatched area*) extends to the Equator. The numbers indicate the approximate distribution of all 17 species. The number 1 is Galápagos penguin; 2, Humboldt; 3, Magellan; 4, gentoo; 5, rock hopper; 6, Adélie; 7, chinstrap; 8, emperor; 9, African; 10, king; 11, macaroni; 12, fairy; 13, yellow-eyed; 14, white-flippered; 15, thick-billed; 16, royal; 17, Sclater.

being kept near a small lake on the outskirts of Baltimore, a herd of Black Angus cattle in the adjoining field came running up. They looked quizzically over the fence, no doubt taken aback to see not a newcomer to the herd but a small, defiant, threatening penguin. We have since learned how to call forth our penguins' various displays on request.

In close cooperation with experts in various fields, we have been studying the penguins' adaptations to captivity, their food requirements, their behavior and their physiology. One of the projects is an attempt to find a treatment for aspergillosis, a common infection of waterfowl and game birds and occasionally found even in man. Collaborating with the pathologist Carlton M. Herman, of the U. S. Fish and Wildlife Service, we have succeeded in cultivating the disease in chickens as an experimental animal and are now in a position to study its pathology and try out drugs.

With Raymond J. Hock of the Arctic Aeromedical Laboratory in Alaska and H. T. Hammel of the University of Pennsylvania we have studied the metabolic rates and heat-conserving mechanisms of our penguins. It seems that penguins, like some waterfowl and seals, have an interesting system of blood-vessel counter-current exchange which prevents loss of heat through their feet and flippers [see " 'The Wonderful Net'," by P. F. Scholander; Scientific American, April]. Finally, with Knut Schmidt-Nielsen of Duke University, we have been running some experiments to find clues to how the Humboldt penguin manages to get along on salty sea water as its sole water supply [see "The Desert Rat," by Knut and Bodil Schmidt-Nielsen; Scientific American, July, 1953].

By studying the beautifully adapted penguins man may eventually learn some hints on survival in very cold climates and on other practical matters. But their main charm to a student lies in the fascination of watching a community of birds which are utterly gregarious and sociable in everything they do. Perhaps some day we shall learn enough about them to be able to rear colonies of them in captivity, so that visitors to zoos can share with explorers of the Antarctic the delightful experience of seeing penguins as they are in nature—squabbling, displaying, pilfering nest material and rearing their chicks.



GROUP OF HUMBOLDT PENGUINS is doing well under the care of Sladen and his wife at the Johns Hopkins University. The Humboldts come from a comparatively warm climate.

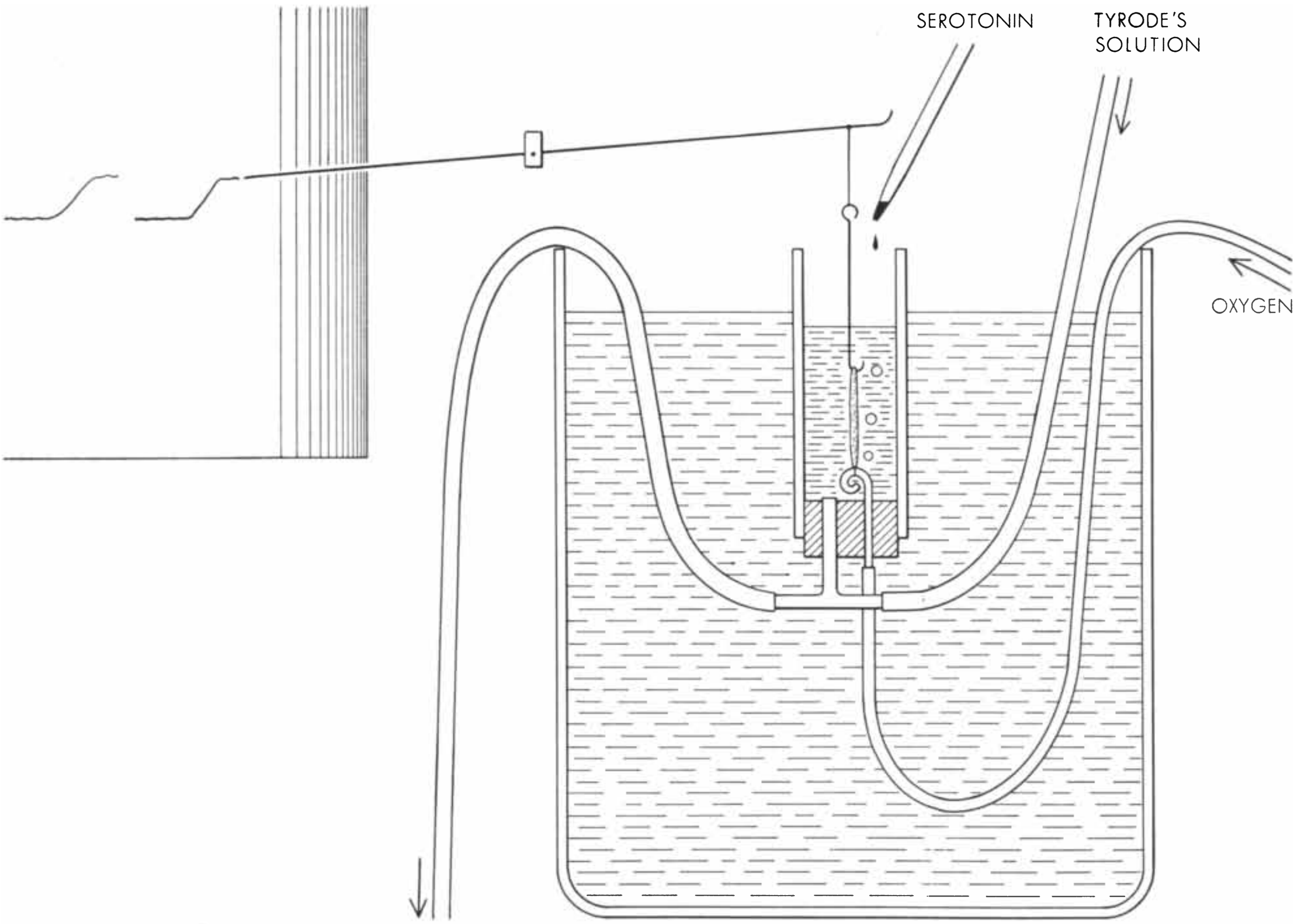
Serotonin

It is a substance found in the blood, the brain, certain tumors, the clam, the octopus, jellyfish and nettles. Discovered only 10 years ago, it is presently a frontier of physiological research

by Irvine H. Page

When we set out in 1939 to look for the substance now known as serotonin, we did so because it seemed a complicating impediment to our studies of high blood pressure. The existence of the substance had been suspected for many years. Noting that the serum of clotted blood caused blood vessels to contract, physiologists had concluded that it contained a substance which, by contracting the vessels, assisted in the plugging of the vessels to stop bleeding from a wound. It is clear how the existence of such a substance in blood could hamper an investigator seeking factors responsible for hypertension. The blood-pressure effects of this normal substance could easily mask those of pathological substances. So we began work to see if we could identify the unknown agent and determine its properties.

Ten years ago we succeeded in isolating this substance, euphoniously named



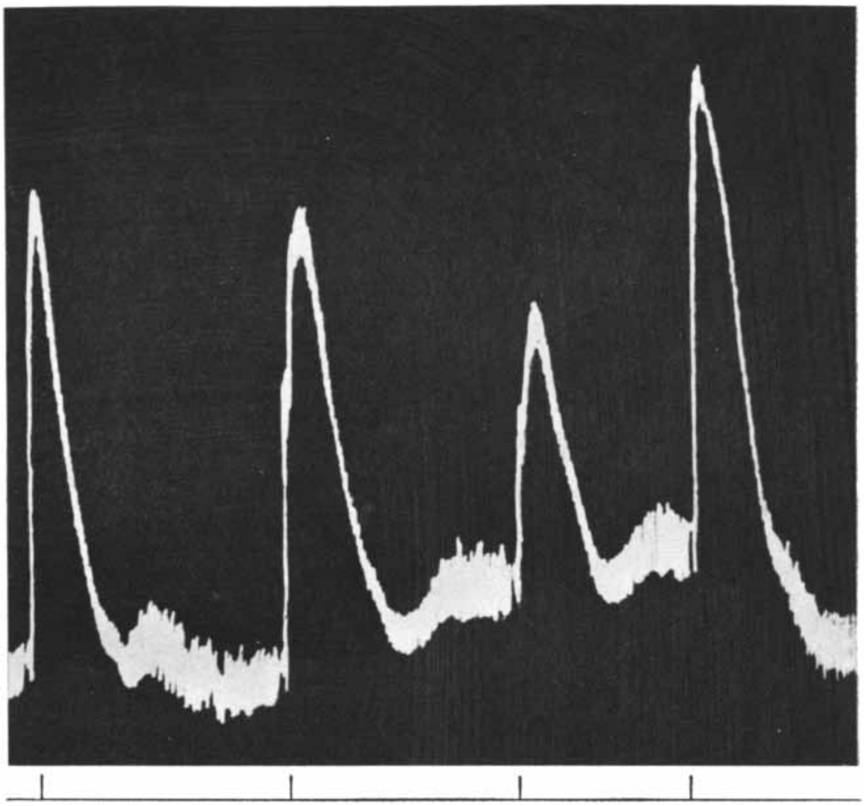
CONTRACTION OF UTERINE MUSCLE in response to serotonin is marked on the moving drum at left as a sharp rise. The muscle is provided with oxygen and Tyrode's solution to keep it alive, and the whole is suspended in a water bath to keep it warm.

serotonin by my colleague A. C. Corcoran. We purified it in crystalline form and determined its chemical structure, after which serotonin was easily synthesized. It has since been made widely available, and investigators have discovered that serotonin is involved in an amazing range of biological processes. Hardly a week now goes by without the appearance of several important papers casting fresh light on the manifold functions of serotonin. It has opened unexpected horizons in biological research.

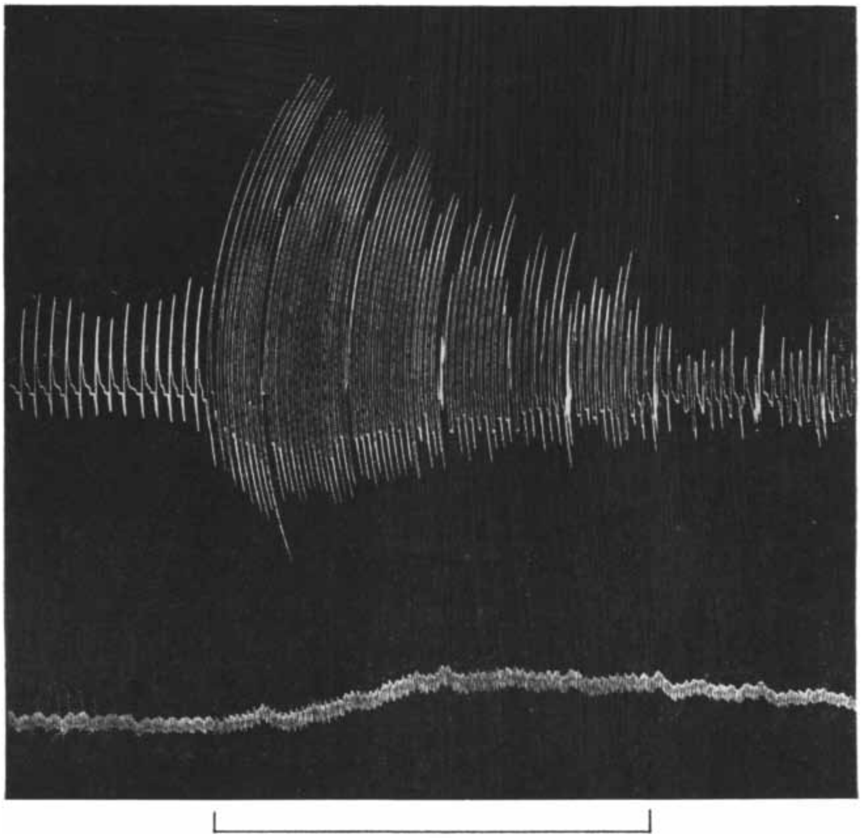
Naturally the first studies of serotonin were of its effects on the heart and blood vessels. It turned out to have a very complicated action on the circulation, and currently there are many theories as to what its main function there may be, ranging from the idea that it regulates the flow of blood through the kidneys to the view that it mediates communication in the nervous system. But research on serotonin soon made clear that its effect on the circulation was only one of the roles that this substance played in the biological world.

Even before serotonin was identified, V. Erspamer in Italy had experimented with it in the form of extracts from animal tissues and found that it had the power not only to raise blood pressure but also to cause muscles of the uterus and the intestines to contract. Erspamer's extracts (whose active ingredient, as he himself later showed, proved to be serotonin) came from invertebrate animals (the salivary glands) as well as from mammals (the gastro-intestinal tissues). Further searches for the substance showed it to be practically ubiquitous, not only in the animal kingdom but also in plants. The nettle seems to produce its sting with a trace of serotonin; so does the jellyfish. Clammed-up clams relax their muscles with it. The octopus has it in its salivary glands, probably for no good purpose. The growth hormones of plants are very closely related chemically to serotonin.

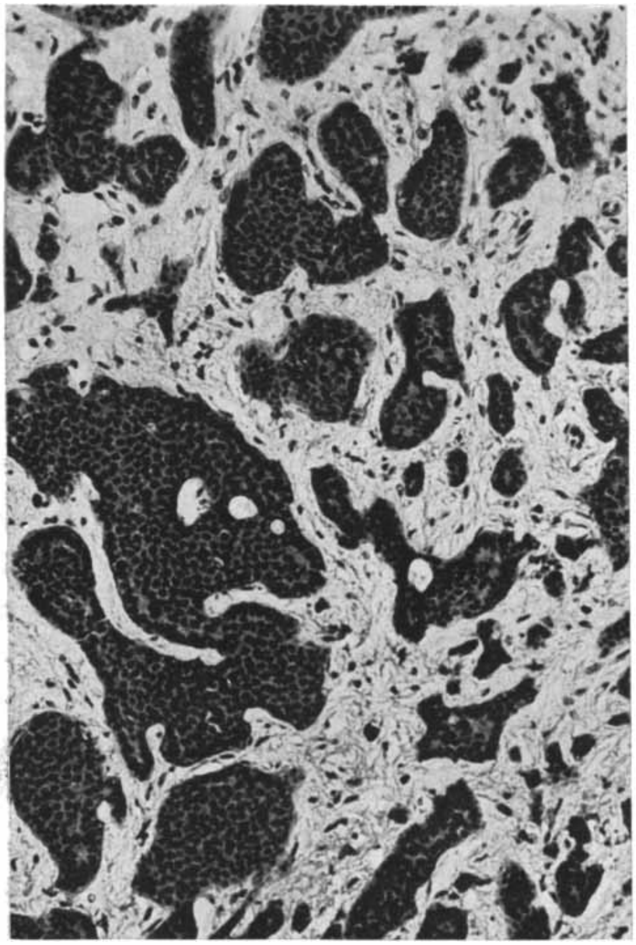
In our own body, and in mammals generally, serotonin has a wide spectrum of effects. Its strong action on the intestines and the uterus suggests that it regulates the behavior of those organs in some way. It seems to be involved in the mechanism of inflammation. It causes the bronchial muscles to contract, which indicates that it may play a major role in some forms of allergy and anaphylactic shock. Indeed, serotonin's potency and wide distribution in the body suggested that it ought to have a specific metabolic disease associated with it; in



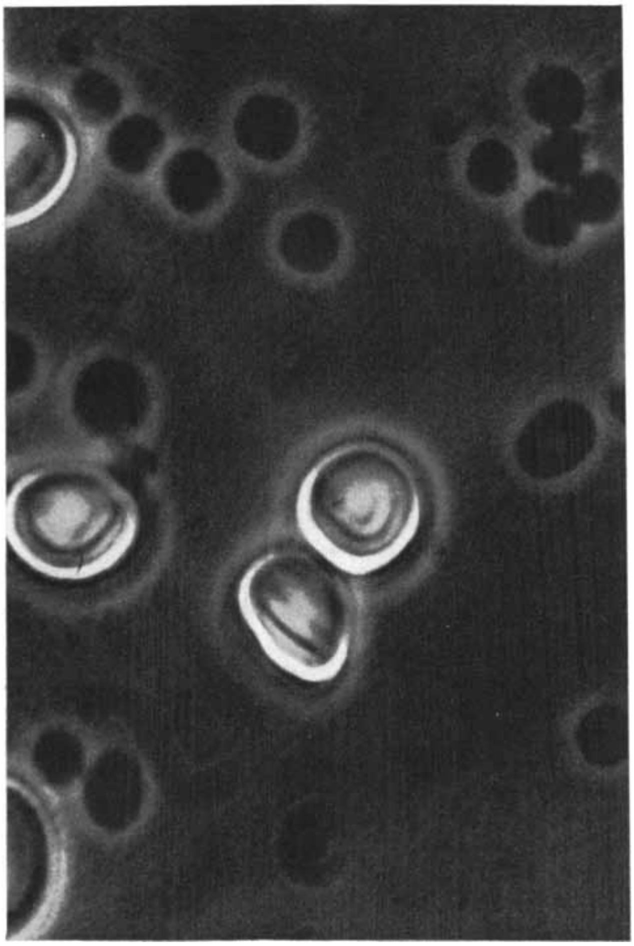
RISE IN BLOOD PRESSURE in an artery after injections of serotonin is shown by the sharp peaks on this record. Lines beneath the tracing mark the time of serotonin injections.



RAPID RESPIRATION results when serotonin is injected slowly into a vein (*upper tracing*). The lower tracing indicates the corresponding rise of blood pressure in an artery. The line below the tracings indicates the period during which serotonin was injected.



CARCINOID TUMOR is shown in cross section by this photomicrograph. The clusters of cells containing serotonin have been stained with silver. They appear as dark spots in the micrograph.



BLOOD PLATELETS, which also contain serotonin, appear as dark disks in this photomicrograph made by Marjorie Zucker of the Sloan-Kettering Institute. The lighter disks are red blood cells.

short, once identified, serotonin could be considered a substance in search of a disease. One was soon found. The disease in question must have been with us since the beginning of descriptive medicine, but it went unrecognized by bedside clinicians until six years after the discovery of serotonin. The symptoms of the disease are skin flushes, abdominal cramps, diarrhea and often damage to the right side of the heart. The disease's focal point is a feebly malignant tumor called "carcinoid." After serotonin became known, it was discovered that the symptoms of this disease were due to secretion of large amounts of serotonin by the tumor. The urine of carcinoid patients was found to contain a high level of a metabolic product of serotonin. Thus carcinoid became the first malignant tumor that could be detected by urine analysis.

But probably the most significant of all of serotonin's functions, in health or in disease, is in the brain. It exerts powerful effects upon the performance of that all-important organ, and serotonin may well become a capital clue to the biochemistry of sanity and insanity.

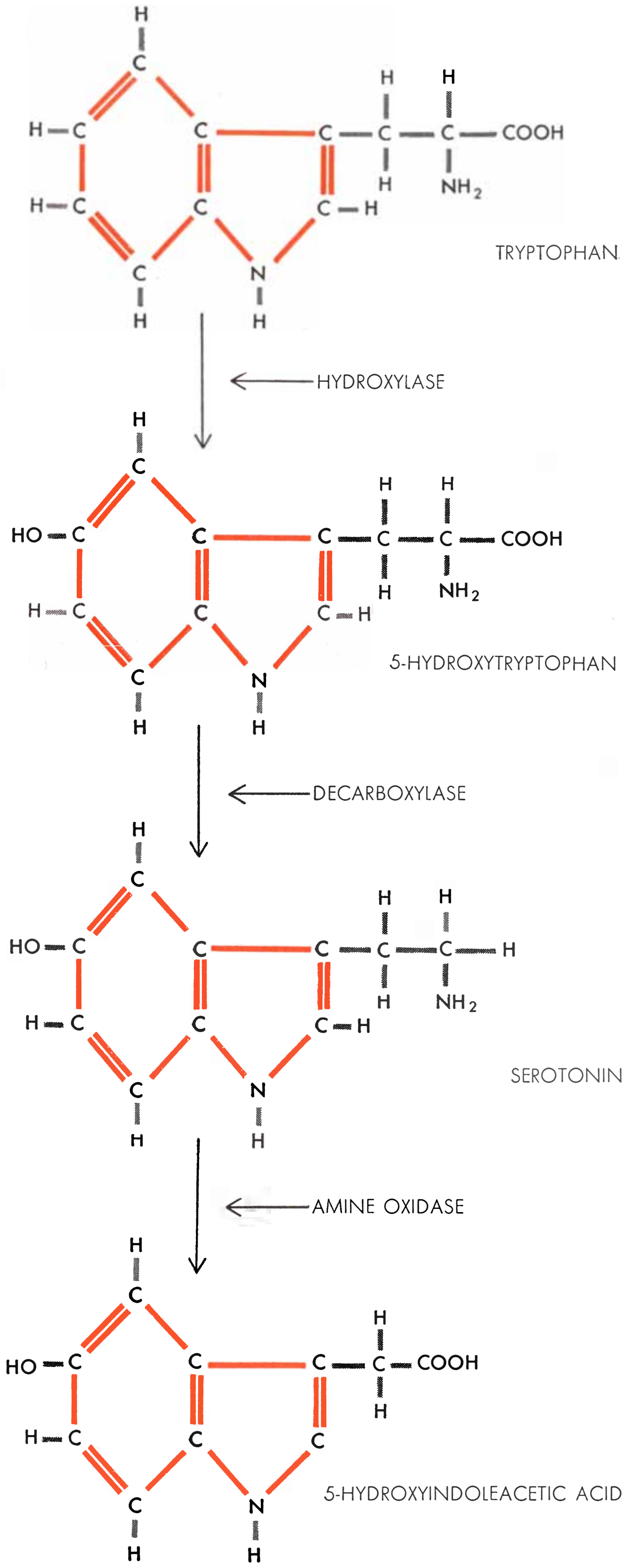
To get a clearer idea of the kind of substance we are dealing with and how it may affect the brain, let us take a quick look at the chemistry and metabolism of serotonin, which were worked out largely by a young biochemist, Sidney Udenfriend, now at the National Heart Institute. The precursor of serotonin is tryptophan, a common amino acid found in protein foods. By a simple two-step reaction involving the addition of a hydroxyl group (OH) and the removal of a carboxyl group (COOH) by two different enzymes, tryptophan is transformed to 5-hydroxytryptamine, that is, serotonin [*see formulas on opposite page*]. Removal of the amine side group by another enzyme degrades serotonin in turn to 5-hydroxyindoleacetic acid, which is excreted by the kidneys. These are common reactions; the enzymes that mediate them do the same in the metabolism of other compounds and are found widely in the cells of the body. The central structure of serotonin on which these additions and subtractions of side groups are performed identifies it as a member of the immensely important family of indoles—a family which includes the plant growth hormones. Herein may lie a clue to some of serotonin's activities: it may account, for example, for the abnormal growth of the lining within the right heart in the carcinoid disease.

At first it was thought that serotonin originated only in a special type of cell which is especially plentiful in the intestine and has the unusual character of staining strongly with silver. Now we know that it can be produced almost anywhere in the body. Some connective tissue cells, in particular, are important releasers of serotonin. In the bloodstream it is largely contained in the platelets. These tiny particles, the formerly mysterious "blood dust," have turned out to be miniature packets of humors, containing histamine and probably other substances that affect the caliber of the blood vessels.

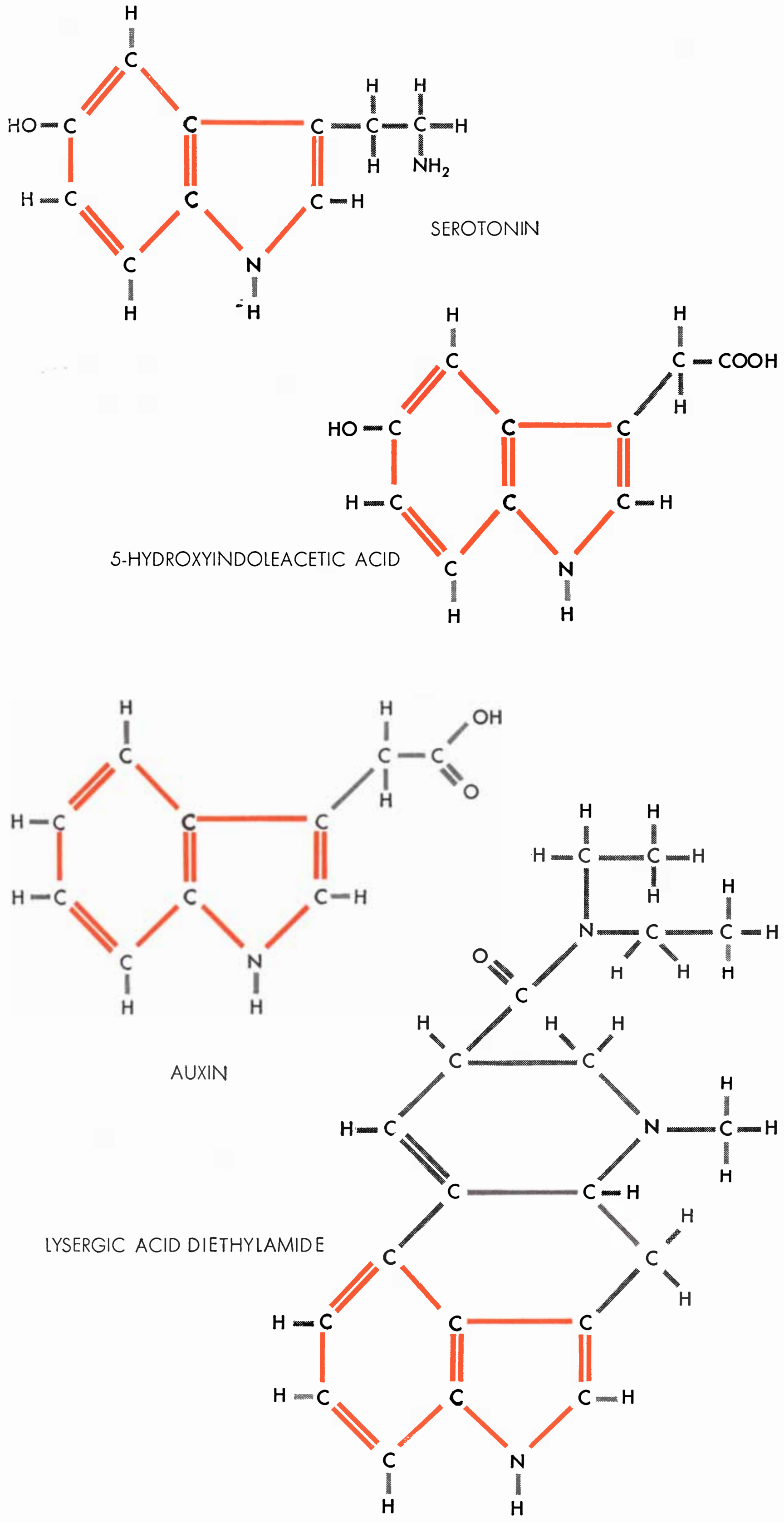
The discovery that serotonin is present in the brain was perhaps the most curious turn of the wheel of fate in this whole business. Several years ago Albert Hofman, a Swiss chemist, had an alarming experience. He had synthesized a new substance, and one afternoon he snuffed some of it up his nose. Thereupon he was assailed with increasingly bizarre feelings and finally with hallucinations. It was six hours before these sensations disappeared. As a reward for thus putting his nose into things, Hofman is credited with the discovery of lysergic acid diethylamide (LSD), which has proved a boon to psychiatrists because with it they can induce schizophrenic-like states at will [see "Experimental Psychoses," by Six Staff Members of Boston Psychopathic Hospital; SCIENTIFIC AMERICAN, June, 1955].

LSD is an indole and thus a cousin of serotonin [*see formulas on next page*]. The connection between them was soon strengthened by the discovery by the British physiologist J. H. Gaddum that LSD blocks the action of serotonin in uterine tissues. Gaddum was moved to suggest that serotonin might be the stabilizer that keeps us sane. Since then a number of other indole antagonists to serotonin have been found or made synthetically; many of them produce changes in behavior and some may have therapeutic properties. D. W. Woolley and E. Shaw, who did much of this work at the Rockefeller Institute for Medical Research, have proposed the bold hypothesis that mental disease may be due to disturbance of the metabolism of serotonin.

Equally suggestive is the interaction of serotonin with the tranquilizing drug reserpine. Bernard B. Brodie, the chief pharmacologist at the National Heart Institute, made the discovery that reserpine liberates most of the serotonin present in the tissues of the brain. The freed serotonin is then rapidly broken down, and is held to a low level in the brain for several days. In Brodie's opinion it is the liberation of serotonin that leads to the signs and symptoms attributed to reserpine. Serotonin injected directly into the brain has, in fact, the same tranquilizing effects. Curiously, when serotonin is injected into the bloodstream it is barred from passage into the brain by the brain's protective chemical barriers [see "Barriers in the Brain," by Robert B. Aird; SCIENTIFIC



SYNTHESIS OF SEROTONIN from tryptophan, an essential amino acid, requires two enzymes. Another enzyme converts serotonin to 5-hydroxyindoleacetic acid, which is the substance excreted in the urine of patients with the carcinoid tumor that produces serotonin.



INDOLE STRUCTURE (*color*) **is the basis not only of serotonin but also of auxin, the plant hormone, and of lysergic acid diethylamide (LSD), which causes experimental psychosis. The breakdown product of serotonin, 5-hydroxyindoleacetic acid, resembles auxin.**

AMERICAN, February, 1956]. However, its precursor, the amino acid 5-hydroxytryptophan, readily crosses the barrier and is converted to serotonin in the brain cells. Small amounts of this amino acid have a sedative action in man, but large amounts are strongly excitant in animals. It may be that free serotonin is sedative in small amounts and excitant in large.

We do not yet have a clear picture of how serotonin brings about its effects. Amedeo S. Marrazzi has shown at the Veterans Hospital in Pittsburgh that in very minute amounts it inhibits the transmission of nerve impulses across the junctions between nerve cells. He postulates that the mental disturbances which have been related to serotonin may be due to this inhibiting action.

We are still far from sure that changes in the serotonin content of the brain are actually the cause of psychosis. About the most we can say at the moment is that LSD and serotonin can induce powerful effects on the brain, and it is reasonable to suppose that these substances or their counterparts are involved in mental health and disease.

It is hard to understand why it took scientists so long to get around to investigating the chemical reactions going on in their own brains. I speak from acute personal experience. When I came home in 1931 after three years of work on the chemistry of the brain at the Kaiser Wilhelm Institute, I could not get a job in this field or stir a ripple of interest in it. There was great reluctance in many quarters to accept the possibility that mental disease might have a chemical basis. Thwarted by lack of opportunity to work as a brain chemist, I moved on to research in cardiovascular disease. Now serotonin has brought me back full circle to my original interest. I find myself fortuitously again in neurochemistry, this time embarked on an odyssey with a substance which promises a most exciting journey.

Wherever serotonin may lead us in the end, it has at least served the useful purpose of playing a big part in bringing the chemistry of the brain to life. Moreover, it has given us a new perspective on how intricately nature works its processes in the body. I suspect that when we finally track down all the functions of serotonin, we shall find them even more subtle and far-reaching than we now imagine. Through serotonin and its chemical relatives we should get a more detailed picture of the complex interplay in the body which makes man greater than his parts.

Kodak reports on:

a photographic plate within the spirit, if not the letter, of Lambert's Law . . . ideas that gel, or turn thixotropic . . . what the founder of the foundry didn't know

In memory of a perfectionist

As Johann H. Lambert must have remarked more than once before he passed away in 1777, wenn die Lichtstärke der von einer Fläche kommenden Strahlung dem Cosinus des Winkels zwischen Strahlrichtung und Flächennormalen proportional ist, so nennen wir die Fläche eine vollkommen streuende Fläche. In short, a perfect diffuser has the same brightness from every direction. A nearly perfectly diffuse *reflector* is fairly easy to come by, but a perfectly diffuse *transmitter* is just a convenient idea, remote from reality.

We like to think that a product we call *Kodak Day View Screens*, though far from the letter of Lambert's Law, comes as close to diffuse transmission as any material available. We make these for optical instruments wherein an image is to be projected from behind the screen with a minimum of "hot spot" at the center to dazzle and annoy. They are clear glass plates precisely coated with one of several compositions that we are rather proud of.

Perhaps the thought occurs to you that a photographic emulsion might be coated over the light-diffusing composition, of a speed such that the plate might be exposed in a camera in order to get some sort of photographic pattern for comparison with a projected image on the screen. The very same thought has occurred to us.

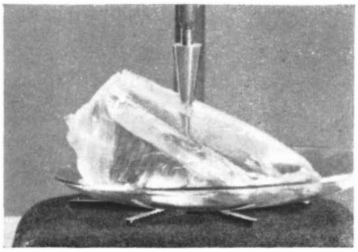
As a result, we now offer Kodak Translucent Plates, Type 5. *Axially the processed plates transmit 85% of the incident light (where unobscured by the photographic image, of course). At 0° they are only eight times brighter than Herr Lambert figured they ought to be, while at 30° they are 0.8 times as bright as he would have wanted. This is much better than it sounds and a whale of a lot better than ground glass. For more technical details and all the commercial details, write Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y.*

Mono-and-water

We have run into a few matters in the field of colloid chemistry that can stand being presented straight. They concern monoglycerides, a kind of fat widely used in baking. Monoglycerides which have been substantially freed of diglycerides by molecular distillation can seize water and imprison it.

• When a monoglyceride at a temperature above its melting point —which for some may not much exceed that of water—is poured into water at the same temperature, a firm gel is instantly formed. The gel contains 15 to 25% of water. Child of what appears to be hydrogen bonding of water to oil, it is dispersible in the former not at all and soluble in the latter only with difficulty. As long as kept warmer than the melting point of the monoglyceride and protected from drying, the gel is indefinitely stable.

• When the pouring is done the other way, viscosity of the equilibrized system rises continuously



until a non-pourable transparent "solid" as firm as putty results.

• Clear homogeneous liquids can be made from water, plain fat, and monoglyceride. The water can carry water-soluble substances while the fat carries oil-soluble substances.

• With liquid monoglyceride, water, and soap, one can make a translucent thixotropic liquid that is contractile, like egg white. When cooled below a certain point, it changes to a crystalline character in which it is like translucent pudding, but still thixotropic. A word like "thixotropy," casually dropped in non-rheological company, can help a person.

Notice how nothing is said about applications? That's because we want you, gentle reader, to have a head start over your competitors. For a full report on mono-and-water, as we see it to date, write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).

The radiographer enlightened

The foundry business managed to get along for several thousand years before we came along peddling our pesky x-ray film. Now it's all different. Even the small foundry, dedicated by the proprietor's grandfather to the peaceful production of parlor stoves, is talked into an x-ray outfit by some slick salesman. And what happens? They're hooked!

Before the year is out, the treasurer reports that the x-ray has already paid for itself. How is that? asks the boss. Why, in metal saved because radiography of the pilot castings pointed out the real danger spots in mold designs and showed where the need for bulk was imaginary.* A little of this kind of talk and soon the radiographer has an assistant radiographer, which leaves him time to take in the annual convention. Now we're rolling. There he runs into other radiographers from places where 400% safety factors on cross-section are not allowed because the darned space vehicles, or whatever they are, would never get off the ground.

Home he comes, not only bearing a bee to put in the foundry sales manager's bonnet, but sounding like this:

"By virtue partly of photoelectron emission and partly of secondary x-rays generated as a fluorescence process, a .005″ sheet of lead foil can serve to intensify an x-ray image on a film in intimate contact with the foil. At the same time, such a lead screen preferentially attenuates the less-penetrating longer wavelengths of the primary radiation. Obviously, both the intensification and filtration effects are strongly kilovoltage-dependent. It has been shown recently that by employing one or both of these effects with two (or even three) films of different (or even the same) speed in the exposure holder, a wider range of specimen thickness can be adequately radiographed in a single exposure, thereby saving dough."

He heard that from a Kodak man named Ralph E. Turner. If you want a clearer idea of what Mr. Turner said, request a copy of the paper from Eastman Kodak Company, X-ray Division, Rochester 4, N. Y.

**The boss knows better than to argue that in the old days job estimates contained a comfortable allowance for rejects. His competition has the x-ray, too.*

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

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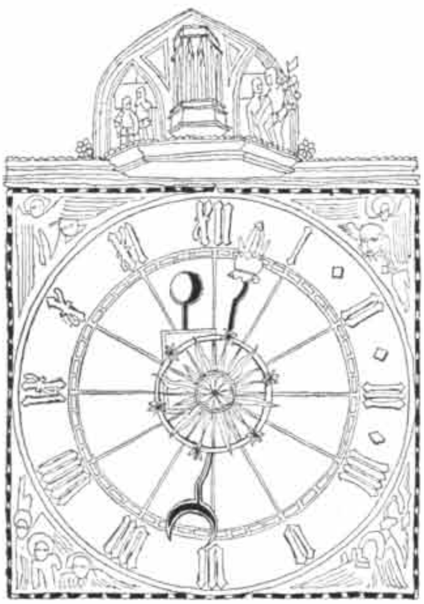
SCIENCE AND



On to the Moon

With the launching by the U.S.S.R. of its second artificial satellite, weighing half a ton and carrying the first living being into space—a little dog named Laika—scientists the world over were ready to accept the age of space travel as already born. A rocket shot to the moon seemed imminent. Experts estimated that the propulsive power which launched Sputnik II would be sufficient to take a payload of more than 100 pounds to the moon.

Although the U.S.S.R. gave out no details on its rockets or the instruments, it was plain that its scientists and engineers had achieved radical advances both in rocket propulsion and in instrumental control. An official statement on the second satellite, issued through the Soviet news agency Tass, said:

"Commenting on the launching of a second earth satellite, Academician Dikushin, a noted authority on mechanics, said that a multistage carrier rocket of a new design with foolproof precision controls had to be used for putting the satellite into its computed orbit. . . .

"The increase in the satellite's size to provide for a large number of measuring and telemetering instruments, and even for an animal passenger, necessitated the development of improved new instruments and sources of power.

"The new Soviet step into cosmic space is a tremendous contribution to world science.

"Astronomers and geophysicists will be greatly assisted by an instrument placed in the satellite for the study of the shortwave spectrum of solar radiation. This radiation directly affects the physical state of the upper layers of the atmosphere and specifically the ionosphere.

"All these studies will give us a deeper insight into solar activity and enable scientists to trace the links between solar phenomena, particularly chromospheric eruptions, and increases in the intensity of shortwave radiation.

"The sputnik carries a special installation for the study of primary cosmic rays which scientists have been unable to study on earth because they change considerably in passing through the atmosphere.

"Now they will be able to delve deeper into the nature of these rays and the properties of atomic nuclei and clear up the origin of cosmic radiation which is now believed to be connected with supernova flare-ups.

"The satellite will undoubtedly provide valuable data on the distribution of chemical elements in the universe which, in turn, will throw more light on the universe's origin.

"Academician Andreyev, an expert in acoustics, said that it was now clear to all that it was not a question of an isolated breakthrough but of a solid mastering of a new branch of science and engineering, the importance of which it was difficult to overestimate even today.

"Astronomer A. Masevich pointed out that the new satellite approached in weight and in distance from earth the 'real' celestial bodies forming part of our system and known as the smaller bodies of the solar system.

"She added that the data received by scientists with the help of the satellite would throw new light on many aspects of physics."

The vital statistics of Sputnik II, as indicated by the early reports, were:

The launching took place at about 6:38 a.m., November 3, Moscow time (10:38 p.m., November 2, Eastern Standard time). The rocket started at a higher first-stage speed than Sputnik I and reached an average of 17,895 miles per hour in its orbit, some 500 miles higher than Sputnik I at the farthest point. The satellite apparently was a rocket-shaped vehicle representing the final stage of the launching rocket. It was said to be cone-shaped with "rather complex" dimensions and a length "many times" its width.

It weighed 1,120.29 pounds and included batteries, radios and instruments for measuring X-rays and ultraviolet rays from the sun, as well as temperature and other conditions. It also bore, in a separate, air-conditioned compartment, a small, hardy female dog related to the Siberian Husky. There were instruments for recording and relaying via radio the passenger's pulse, blood pressure and respiration, and a device for feeding it a rich liquid diet.

Sputnik II's orbit, like Sputnik I's, was inclined 65 degrees to the Equator. It made a circuit of the earth in 103.7 minutes. The closest approach to the earth (perigee) was variously estimated at 100 to 200 miles, and the highest point (apogee) was given in a Soviet announcement as 1,056 miles.

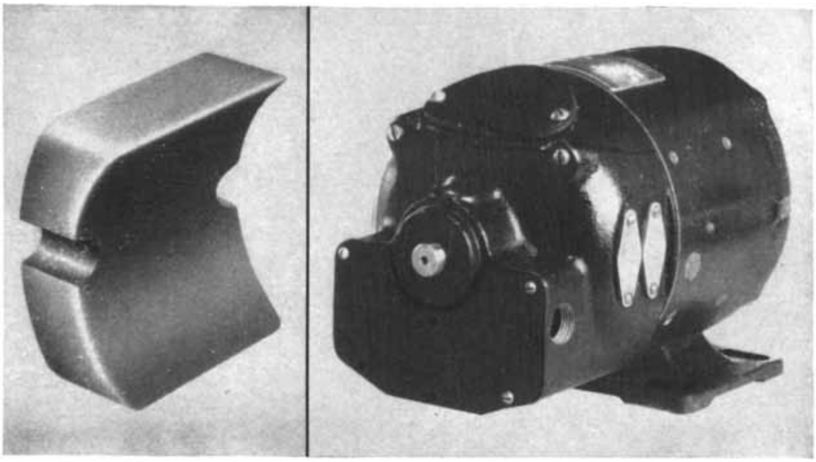
Radio information was again supplied by two transmitters broadcasting at 20.005 and 40.002 megacycles. The lower frequency transmission was divided into .3-second beeps separated by equal pauses; the higher frequency was a continuous signal.

Nobel Prizes

The Nobel science prizes for 1957, worth about $42,000 each, were given in medicine and chemistry for achievements of earlier years and in physics for a discovery barely out of the headlines.

The physics winners, among the youngest men ever to receive a Nobel award, were the Chinese-born theoretical physicists—Chen Ning Yang, 34, of the Institute for Advanced Study, and Tsung Dao Lee, 30, of Columbia University—who challenged the "law" of the conservation of parity and suggested the experiment which proved they were right [see "The Overthrow of Parity," by Philip Morrison; SCIENTIFIC AMERICAN, April]. A whole series of experiments since then has shown that particles involved in "weak interactions," such as beta-decay emissions, are not symmetrical but have an innate right- or left-handedness.

The Nobel prize in chemistry was awarded to the 50-year-old British organic chemist Sir Alexander Todd for



his pioneering work on nucleotides. These substances make up most of the coenzymes which power biochemical reactions, and are also the building blocks of nucleic acid, the genetic material. Nucleotides are complex combinations of bases known as purines and pyrimidines with sugars that contain phosphate groups. Todd, who is professor of chemistry at the University of Cambridge, was the first to synthesize a number of important nucleotides, including adenosine triphosphate (ATP) and adenosine diphosphate (ADP). He has also done fundamental research on the structure of nucleic acids.

Winner of the Nobel physiology and medicine prize was a Swiss-born pharmacologist, Daniel Bovet, also 50, of the Istituto Superiore di Sanità in Rome. Bovet was one of the early students of antihistamine compounds and discovered their chemical structure. Then he turned to the problem of muscle relaxants. He analyzed the Brazilian arrow poison, curare, and synthesized hundreds of compounds with similar physiological effects. Out of this work has come the widespread use of succinylcholine as a muscle relaxant in surgery. Currently Bovet is interested in the chemistry of the brain and its relation to mental illness.

I.A.E.A.

The International Atomic Energy Agency last month began its active life with a meeting of the 55 member nations in Vienna. U. S. Congressman W. Sterling Cole was appointed director general for a four-year term. Pavel Winkler of Czechoslovakia was elected chairman of the board of governors. At the meeting Portugal offered to make available to the agency 220,000 pounds of uranium ore, which would yield about 1,600 pounds of metal. Previously the U. S. had said it would supply 11,000 pounds of uranium and the U.S.S.R. had offered 110.

Jobseekers

Most physics graduate students seem to be ignoring the offers of personnel recruiters for U. S. industry in favor of academic life, even at a sacrifice of up to $2,000 a year in salary, according to a recent survey. The survey, based on records of the placement service of the American Institute of Physics, was carried out by J. N. Gadel (a physicist) and G. A. Peters (a psychologist) and reported in *Physics Today.*

According to the applications to the

SILICONE NEWS

"Make it Better" with Silicones

- Longer lasting cosmetics made with water repellent silicones
- Silicones improve appliance finishes
- Better packaging with silicone coated papers

SOMETHING OLD, SOMETHING NEW, *something familiar but different, too... this is the range of products being improved with Dow Corning Silicones. Why make it better with silicones? Lower production costs for one reason. But as these current examples indicate, silicones also help create more customer satisfaction, more sales.*

LONGER LASTING LOTIONS — Yesterday: no matter how often Mrs. Consumer applied hand lotions, her skin was still vulnerable to household detergents and cleaners.

Today: the cosmetic industry is marketing longer lasting and more protective beauty preparations made with Dow Corning Silicones. Already an accepted ingredient in sun-tan oils, hand creams and baby lotions, the silicones turn back water like an invisible glove . . . help keep the soothing ingredients on the skin longer.

Latest survey found most name cosmetic houses evaluating silicones for products ranging from hair sprays to foot ointments. And they're telling their customers about silicones, too. More and more, at cosmetic counters everywhere, you hear Mrs. Consumer say, "I'll take the one with silicones."

NEW APPLIANCE "SALESMAN"— The familiar refrigerator display cases in our supermarkets have long had a coating equally familiar . . . porcelain. Now, there's something new under the fluorescents . . . chip resistant silicone enamels.

A major producer of these display cases, Scherer-Gillett of Marshall, Mich., reports that their silicone finished cabinets stay new looking longer . . . do a better job. The silicone enamel—Nubelon S, made by Glidden — has excellent color retention; withstands more abuse from shopping cart impacts, food stains, and abrasive cleaning compounds. Available in several attractive colors, the silicone enamels enable Scherer-Gillett to produce cabinets that weigh less, cost less to ship, and are easier to handle and install.

Next major area of application for enamels made with silicone resins? Right now they're rapidly gaining favor in the home appliance market.

PACKAGING STICKY PRODUCTS? Then consider the new silicone coated papers and paperboards now available. Virtually nothing will stick to these new packaging materials, thanks to the anti-adhesive silicone coating developed by Dow Corning. Applied at the mill, the silicone coating makes it possible for users of paper bags, boxes and wrappers to get even the stickiest products out of containers without waste. Producers of rubber, asphalt, adhesives, sticky foods . . . all can now offer their customers greater convenience and ease of handling at little or no extra cost. In the

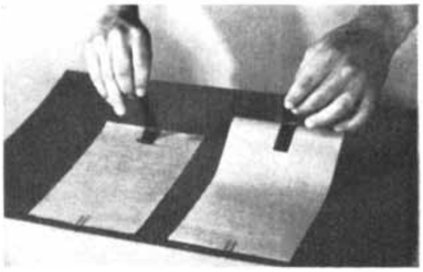


photo you can see how adhesive tape flicks off a silicone coated interleaving paper while clinging to an untreated paper.

FOR MORE INFORMATION **on any of these silicone products or applications, write Dept. 9824**

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CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST GOBAIN, PARIS placement service, 40 per cent of the graduates preferred a job in a university, 18 per cent in other institutional work, 8 per cent in government and 34 per cent in industry. On the other hand, jobseekers with only a B.S. degree overwhelmingly preferred work in industry.

Underground Power

By mid-1958 New Zealand will have the world's first big electric power plant driven by volcanic steam. The steam will come from the Lake Taupo area of North Island, one of the earth's few geothermal regions. There, as in Yellowstone National Park and parts of Iceland, the water table comes in contact with hot subterranean rocks, producing geysers, steam jets and pools of boiling mud.

New Zealand, which leads the world in per capita consumption of electricity, has turned to geothermal energy to meet a crisis in power supply. With little coal and no petroleum, the island has been relying on hydroelectric power, but this will not long provide for the population, now growing at the phenomenal rate of 2 per cent per year. Volcanic steam, it seems, is the perfect answer to New Zealand's problem. Not only is it available near big cities, but it can be tapped anywhere over an area of more than 3,000 square miles. One small test-bore, according to a report in *Science*, already produces 130,000 pounds of water and steam per hour. Its roar can be heard four miles away.

The power plant, which will turn out 69,000 kilowatts, will be built for the government at a cost of six million pounds. It will utilize dry, superheated steam from high-pressure bores. If wet steam and hot water also can be used, its output may rise to 250,000 kilowatts.

Heart Trouble

Coronary disease is not rising as rapidly in the U. S. as has been thought, nor can it be clearly attributed to diet as a major cause, according to some recent studies which were reported last month.

Edward A. Lew, a Metropolitan Life Insurance Company actuary and statistician, discussed mortality figures in the *Journal of Chronic Diseases*. He decided that the supposed 50 per cent increase in the U. S. coronary death rate in the past two decades could be accounted for as follows: 30 per cent of the increase is due to the greater proportion of old persons in the population;

Who's the big wheel in inertial navigation?

Taking a ride on the clockwork of the universe . . . drawing on information sealed in at departure . . . free from jamming or any other remote interference—inertial navigation can guide self-powered vehicles, vessels or missiles to any spot on earth or beyond.

Several leading firms helped develop inertial navigation. However, ARMA was selected to design and produce the guidance system for Titan—America's newest intercontinental ballistic weapon.

That fact helps spell out the calibre of the brains, the imagination, and the production skills that ARMA brings to bear on problems in advanced mechanical, electromechanical and electronic systems. ARMA . . . Garden City, N. Y. A Division of American Bosch Arma Corporation.

There are challenging employment opportunities in inertial navigation at ARMA

AMERICAN BOSCH ARMA CORPORATION

40 per cent to more accurate classification of the causes of death, and most of the remaining 30 per cent to a broader concept of coronary disease and better diagnosis. Lew concluded that the real increase in mortality from coronary disease was less than 15 per cent.

George V. Mann, a Massachusetts physician, pointed out in an article in the *American Journal of Medicine* that reports of sudden deaths as due to causes such as cerebral hemorrhage and heart failure in chronic kidney disease have decreased substantially in the past 15 years; he concludes that many deaths formerly attributed to these causes are now chalked up to coronary disease. Mann also observes that while coronary mortality in some European countries dropped during the fatless diet period of World War II, other countries in the same situation showed no decrease. Furthermore, the death rate in England began to rise again before fats were restored to the national diet.

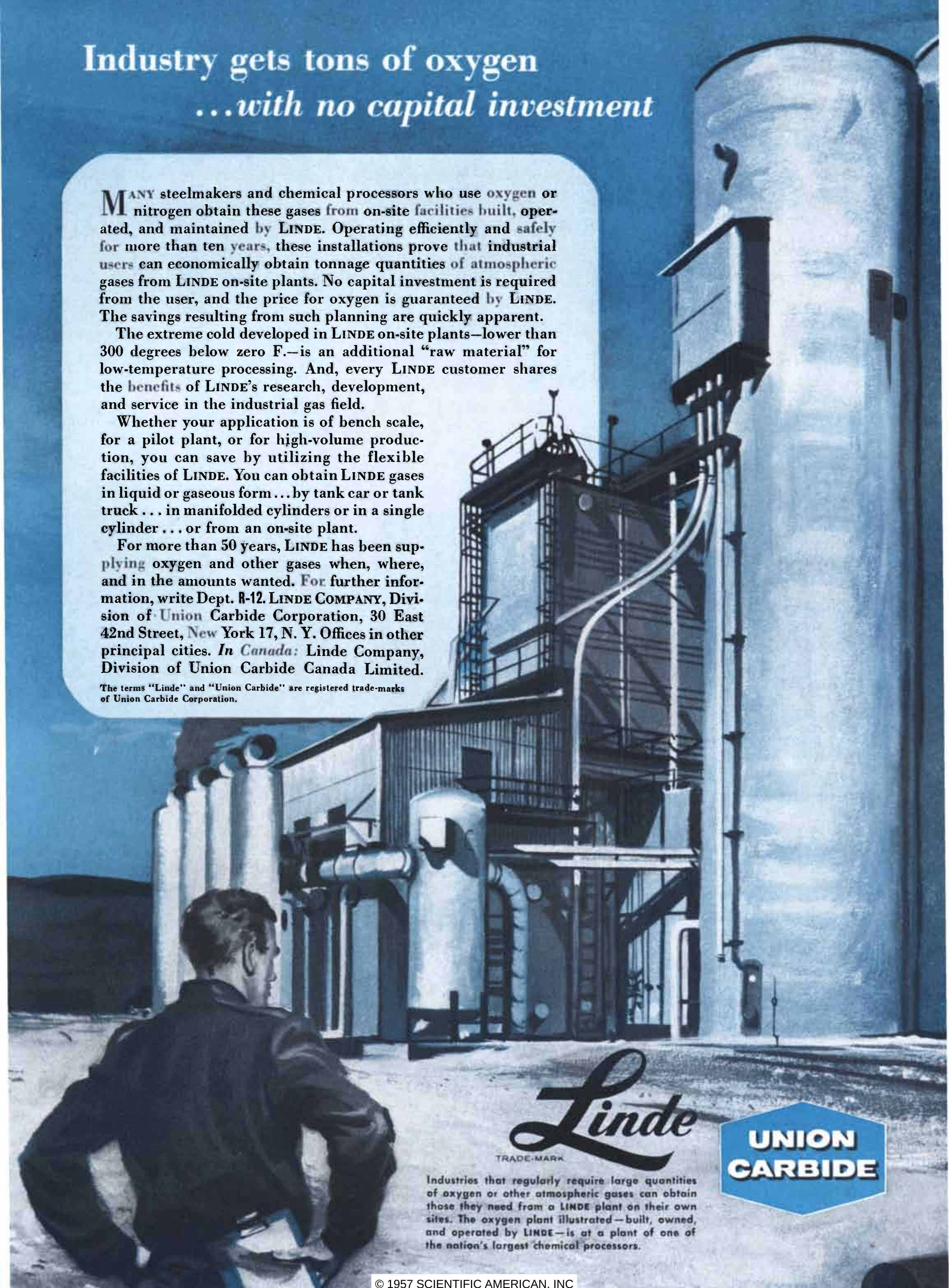
A committee of the American Heart Association, after reviewing the myriad studies on dietary fat, came to the conclusion that "the evidence does not justify a rigid stand on what the relationship is between nutrition, particularly the fat content of the diet, and atherosclerosis and coronary heart disease."

Witchweed

About five years ago farmers in North and South Carolina began to be troubled by a mysterious "disease" that stunted and wilted their corn. Last year a student from India, examining some affected corn plants sent to the North Carolina State College, discovered the cause. He recognized a parasitic plant attached to the corn roots—a parasite which is notorious in India, Burma, Australia and Africa as a destroyer of grain crops. The pest, not previously found in North America, is a handsome little plant with red flowers which is called witchweed.

The seed of the witchweed lies dormant in the ground until the root of a grass plant such as corn comes near it. Some substance from the root then arouses the seed: it germinates and pushes a root of its own into the juicy corn rootlet. For four to six weeks it sucks juices and plant foods from its host; then it sends green shoots above ground and produces blossoms and seed pods.

Once witchweed has infested an area it is hard to eradicate, for a single plant can produce 50,000 to 500,000 tiny dustlike seeds, and the seeds can lie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MANY steelmakers and chemical processors who use oxygen or nitrogen obtain these gases from on-site facilities built, operated, and maintained by LINDE. Operating efficiently and safely for more than ten years, these installations prove that industrial users can economically obtain tonnage quantities of atmospheric gases from LINDE on-site plants. No capital investment is required from the user, and the price for oxygen is guaranteed by LINDE. The savings resulting from such planning are quickly apparent.
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dormant in the soil for as long as 20 years until they find a host. South African farmers, who have had long experience with the weed, find the best solution is to grow trap crops, such as peanuts and certain legumes, which make the witchweed seeds germinate without supporting their growth; the farmers plow the plants under before the witchweed seedlings can bloom and produce new seeds. Another method of control is a chemical spray such as 2,4-D.

Fortunately witchweed does not spread rapidly. The infestation in the Carolinas probably originated as long as 10 or 15 years ago, in the opinion of A. R. Saunders, a South African expert on the subject. Agricultural agents have quarantined the affected counties in the Carolinas and started a campaign to eliminate the weed. Research teams in the laboratories of the U. S. Department of Agriculture in Beltsville, Md., and at Clemson Agricultural College in South Carolina and North Carolina State College are investigating potential controls such as soil fumigants, herbicides and crop rotation. They anticipate a long, slow battle with witchweed. For the present, control depends primarily on the farmers.

Moth Ear

Nature has a connectedness that is sometimes astounding. The ultrasonic cries that bats use for echo-location, for instance, would seem to be of no concern or use to anybody but the bats. It now develops, however, that these high-pitched beeps also act as a warning to moths on which the bats prey!

Kenneth D. Roeder of Tufts University and Asher Treat of the City College of New York made this discovery. They exposed the hearing organ of the southern army moth, a favorite food of insect-eating bats, and connected it to electrodes. Stimulation of the moth ear then was signaled by spikes on an oscilloscope. The scientists released a bat to fly around the room. Although they could hear nothing, because the bat's cries are above the frequency range of the human ear, the oscilloscope showed volleys of spikes from the nerve responses of the moth's ear. The ear also responded to the sounds of a Galton whistle (the "silent" dog whistle).

The investigators found that the moth ear is beautifully adapted to hearing and locating high-pitched sounds. Unlike the ear of most other animals, even of insects, the moth's ear has only two receptor cells, one reacting more slowly than the other. It apparently hears only

noises ranging from sibilant sounds such as the rustling of grass and birds' whistling to ultrasonic vibrations inaudible to man. Moths can probably detect a bat coming at them when it is still about 10 feet away. They may also be able to hear the sounds of predatory mice and birds.

That is not all. Nature's wheels within wheels go on without limit. Treat found that there is a parasitic mite which lives on this moth, and it finds the moth's ear especially nourishing. But it never eats both of a moth's ears—only one. If it deafened the moth, its host would become easy prey for bats, so the remarkably adapted parasite leaves the moth with some hearing for its own protection.

Nuclear Operating Procedure

Nuclear power plants will soon be in regular operation in the U. S. What will running them be like? Engineers of the Westinghouse Electric Corporation's atomic power division have given in a company house-organ a preview of the procedures for operating the pressurized-water reactor plant now nearing completion in Shippingport, Pa.

Starting up a cold nuclear plant takes about eight hours, as against five or six for a coal-fired plant. It will take half an hour to pull out the control rods gradually so that the reactor does not overshoot the critical level. Then the core must be warmed very slowly, to avoid damaging its walls.

A pressurized-water reactor tends to adjust its own reaction rate to the power being drawn from it. Nevertheless, it cannot safely be left unattended. The engineers suggest that the auxiliary equipment in the plant should have no more automatic controls than necessary. This will keep down capital costs and give work to the necessary stand-by crew. They estimate that the Shippingport station will be manned by 81 men. A comparable conventional plant requires 66.

A big problem in stopping and starting operations is occasioned by xenon 135, one of the fission products. It has a gluttonous appetite for neutrons; consequently, when the reactor is restarted, xenon eats up so many neutrons that the control rods must first be pulled far out to make the chain reaction go and then pushed back in quickly as soon as the xenon is transformed to other elements with a less avid appetite for neutrons.

Once a year or so the reactor's fuel charge must be replaced. The process requires about a week, the authors say.

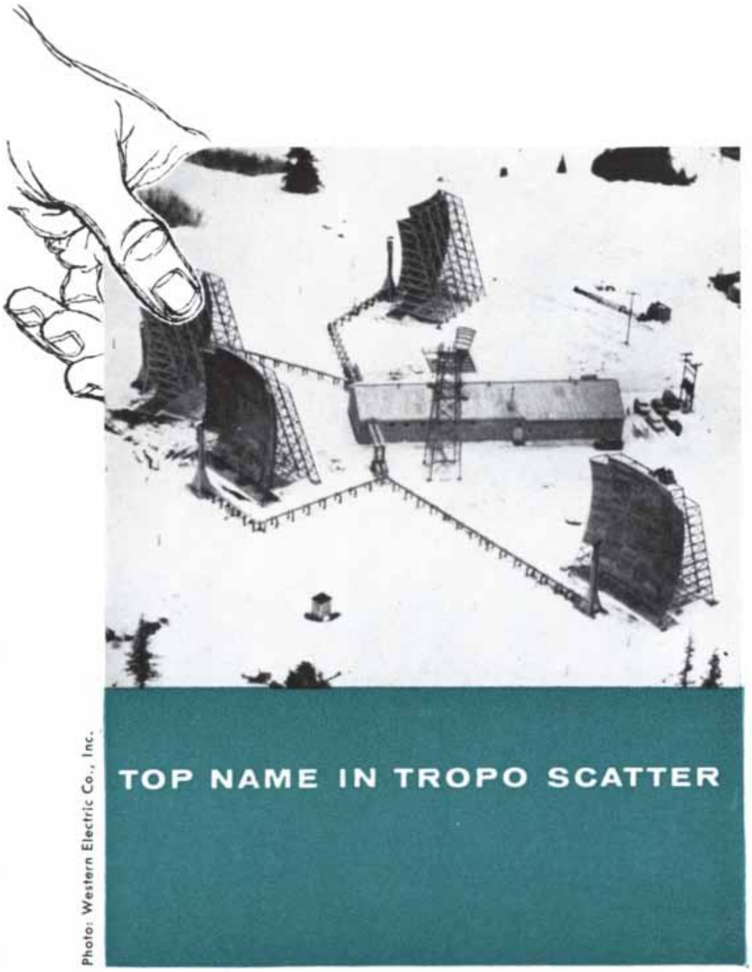

Photo: Western Electric Co., Inc.

Detailed information and technical data on the tropospheric scatter radio equipment for four major projects has recently been published by REL.

Entitled *Top name in tropo scatter,* this manual describes the radio apparatus developed and manufactured by REL for the first major project, Polevault; for the largest, White Alice; for AN/FRC-39; and for the Texas Towers, AN/FRC-56.

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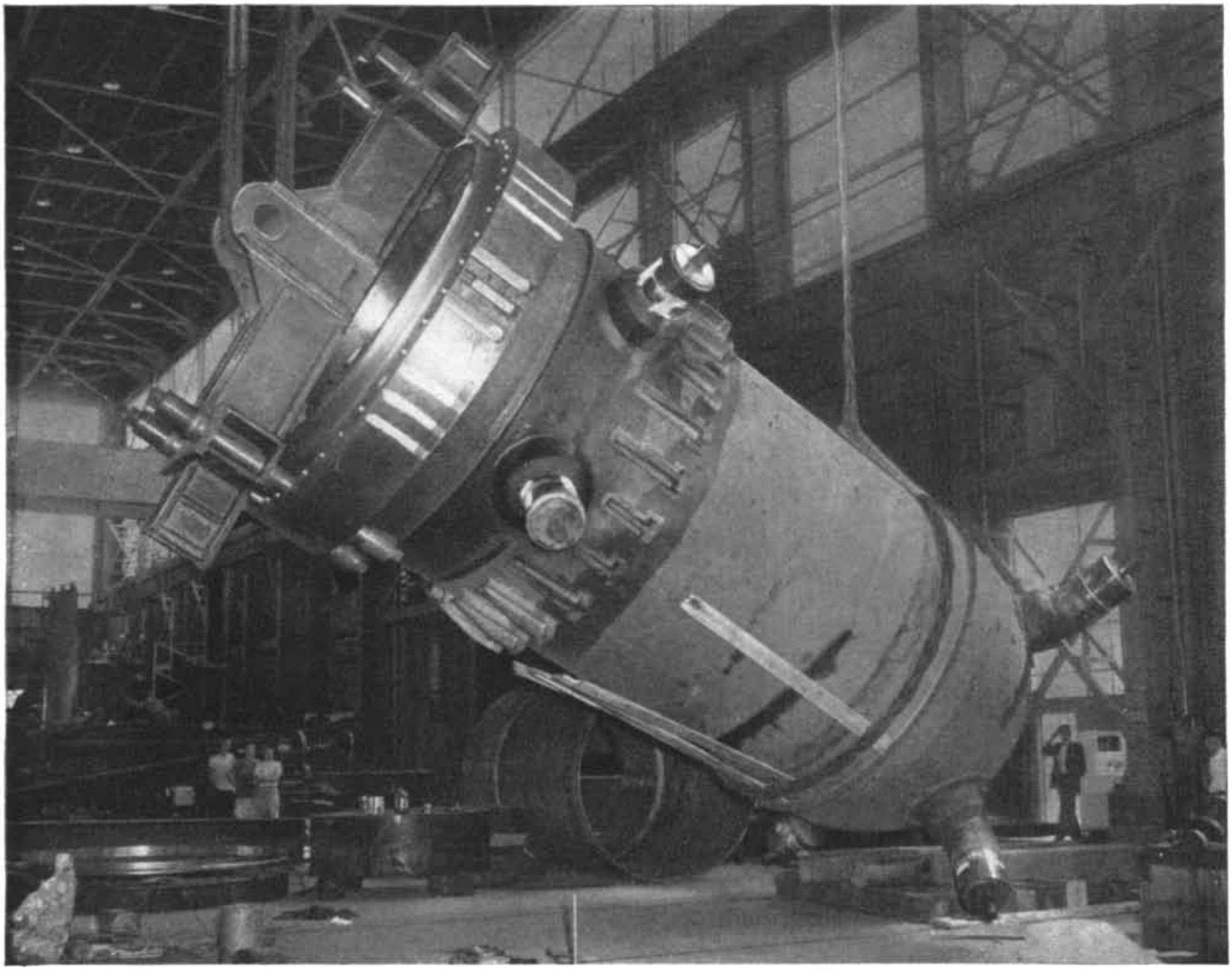

Bringing home the atom. Electricity will soon flow from the first full-scale nuclear power plant in America. This 235-ton reactor vessel was designed and built with alloy steels and nickel alloys by Combustion Engineering, Inc. It will supply power for the 60,000 kilowatt Shippingport plant designed by Westinghouse Electric Corporation.

In Shippingport atomic reactor...

Inconel "X" will keep "hungry water" on a starvation diet

"Hungry water" is the apt name for high-purity coolant that whirls through the super-hot core of a nuclear reactor.

It tries to feed on anything it touches!

Its immoderate appetite explains why the reactor for America's first full-scale commercial nuclear power plant had to be designed and constructed as it was—*with core mount springs made of Inconel "X"* age-hardenable nickel-chromium-iron alloy.*

Other spring materials would relax long before operating temperatures hit their peak above 500°F. Or they might fail completely from what is called "stress-corrosion cracking", or embrittlement. In either event, it would be impossible to make repairs because of radioactivity.

It was this consideration that practically dictated the choice of Inconel "X" alloy. An exceptionally tough spring material, Inconel "X" alloy stands up to heat . . . corrosion . . . stress. In a lifetime of use, it's not expected to give "hungry water" a morsel of encouragement!

Have you a metal problem that you'd like to "starve off", too? One where corrosion, high or low temperatures, stress or fatigue is causing trouble? Talk it over with us. And if your problem involves springs, as this one did, write for our new *Technical Bulletin T-35.* Containing complete design information on Inco Nickel Alloys for helical springs, it's sure to prove a valuable addition to your engineering reference files.

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FUSION POWER

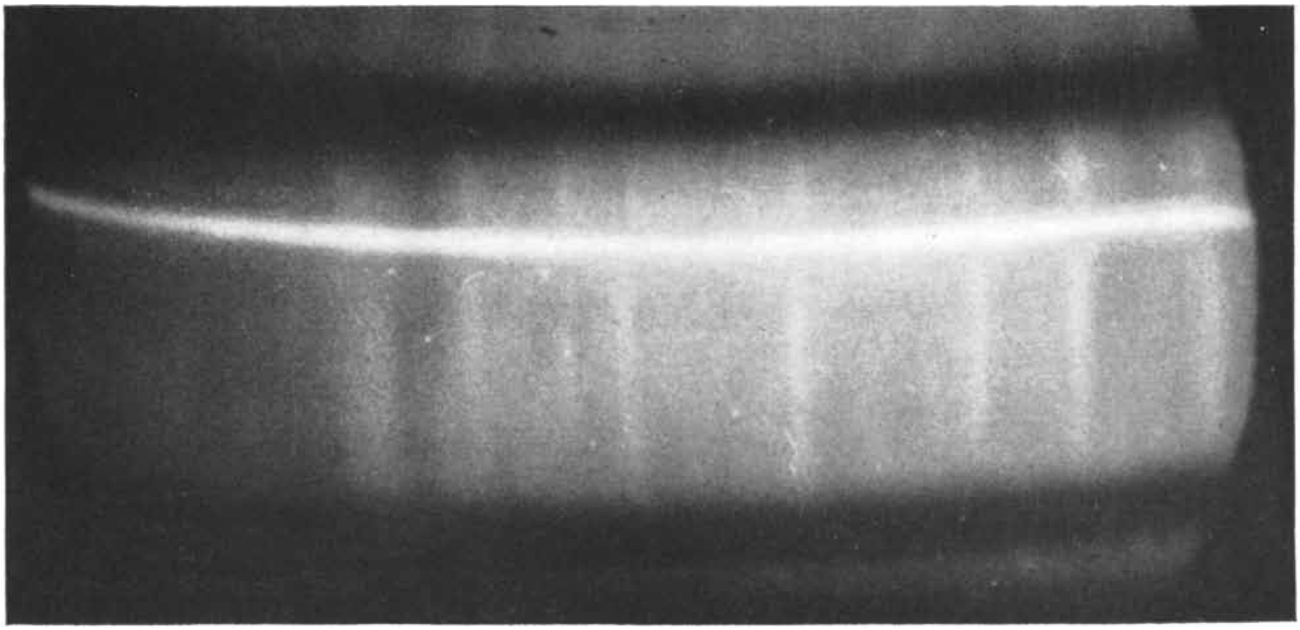
If man can tame the reactions in which the nuclei of atoms are fused rather than split, he will have an almost limitless source of energy. The problem is now being attacked in laboratories all over the world

by Richard F. Post

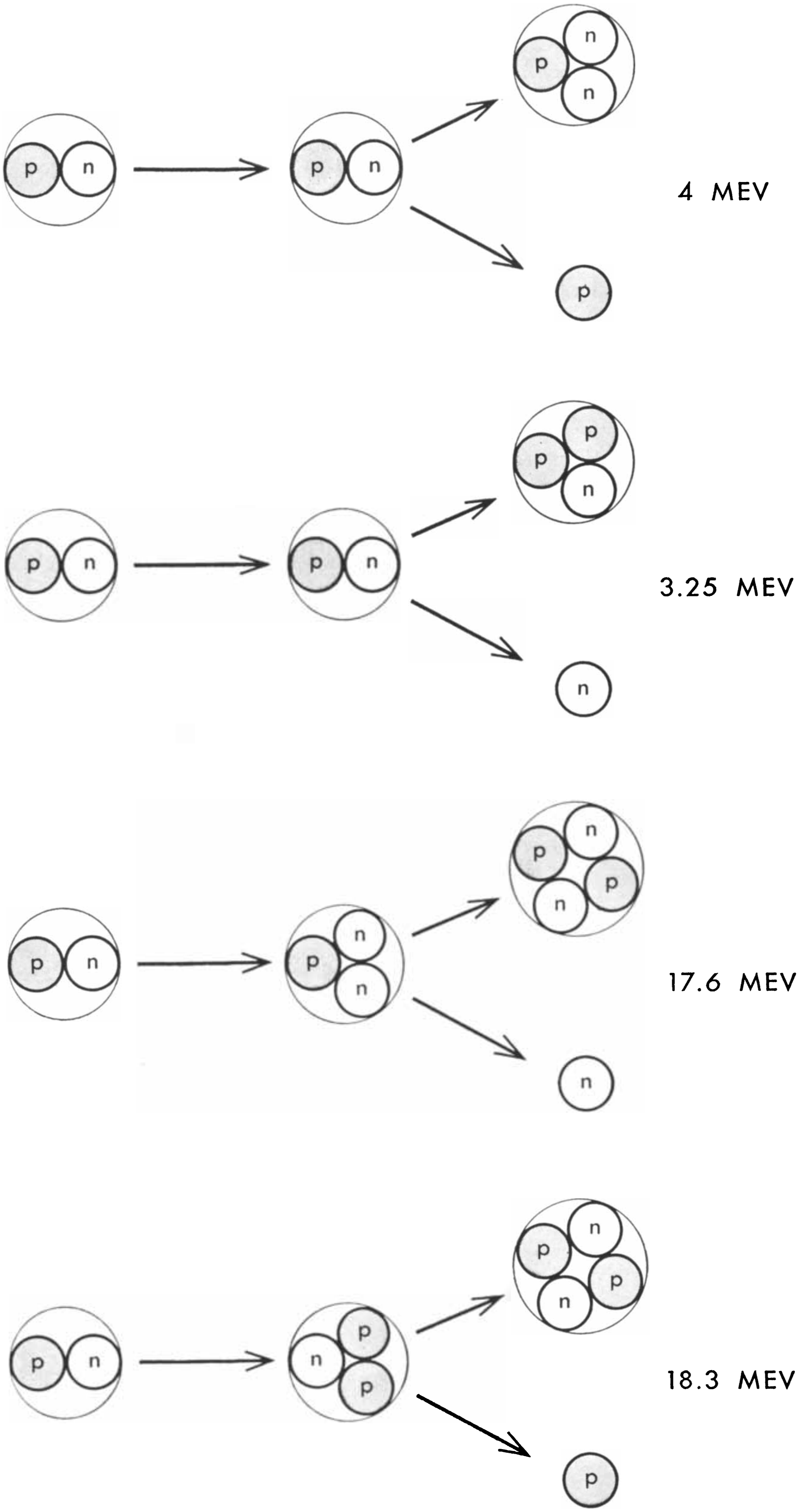
The effort to "tame" the hydrogen bomb reaction—to harness the energy of nuclear fusion for controlled power—is gaining momentum in many countries of the world. It is proceeding quietly, behind a screen of official secrecy, but nonetheless vigorously and on a substantial scale. Every nation has come to recognize that this research effort may well be the most important in the history of mankind. The ultimate stakes are so high, for nations individually and mankind collectively, that a growing sense of urgency and determination is infusing the work of the several nations on this problem.

The upsurge of our industrial civilization in the first half of the 20th century was founded upon fossil fuels—coal and oil. But there are many "have-not" nations, and even countries rich in these fuels are now seeing rapid inroads into their reserves. At this juncture uranium has come to the rescue as a hope for the future. Already electrical power is beginning to flow from the first nuclear fission plants. The United Kingdom expects to go over to fissionable fuels for most of its energy needs within a few decades, and many other countries are laying plans to follow suit; even the U. S., with its great reserves of coal, is spending hundreds of millions of dollars to prepare for turning to fission power at a not too distant date.

The world's uranium and thorium, it is estimated, represent an energy reserve somewhere between 10 and 100 times larger than its remaining coal. Even so, fissionable fuels, too, are an exhaustible supply. At the rate at which the world's energy needs are expanding (the U. S. has doubled its electrical power requirements every eight years) practically all of the economically recoverable uranium, as well as coal, might be exhausted within another century or so. Fission power also presents a more immediate problem: namely, disposal of its radioactive wastes. If the present power needs of the U. S. were all supplied by fission reactors, we would have to dispose each year of an amount of radioactive fission products equal to that from the explosion of 200,000 atomic bombs; by the year 2000, with increased use of power, the radioactive wastes



HOT PLASMA (an electrically neutral mixture of positive ions and electrons) is seen as a bright horizontal line in this image-amplifier photograph. The gas is heated and constricted by the "pinch effect," produced by a current of 8,000 amperes. This experiment, using krypton gas at a pressure of two ten-thousandths of an atmosphere, was done at the Los Alamos Scientific Laboratory.



FUSION REACTIONS which promise to be useful for production of power are shown schematically. At top two deuterons merge to form a tritium nucleus (triton). Second is the equally probable reaction in which the deuterons form helium 3 and a neutron. Third, a deuteron combines with a triton to form helium 4 and a neutron. At bottom a deuteron fuses with helium 3, producing helium 4 and a proton. The amount of energy released in each reaction is listed at its right. Protons and neutrons are designated as "p" and "n".

would come to the equivalent of eight million atomic bomb explosions per year! It is clear that the problem of safe disposal of radioactive ashes and gases in the coming age of fission power will soon become staggering.

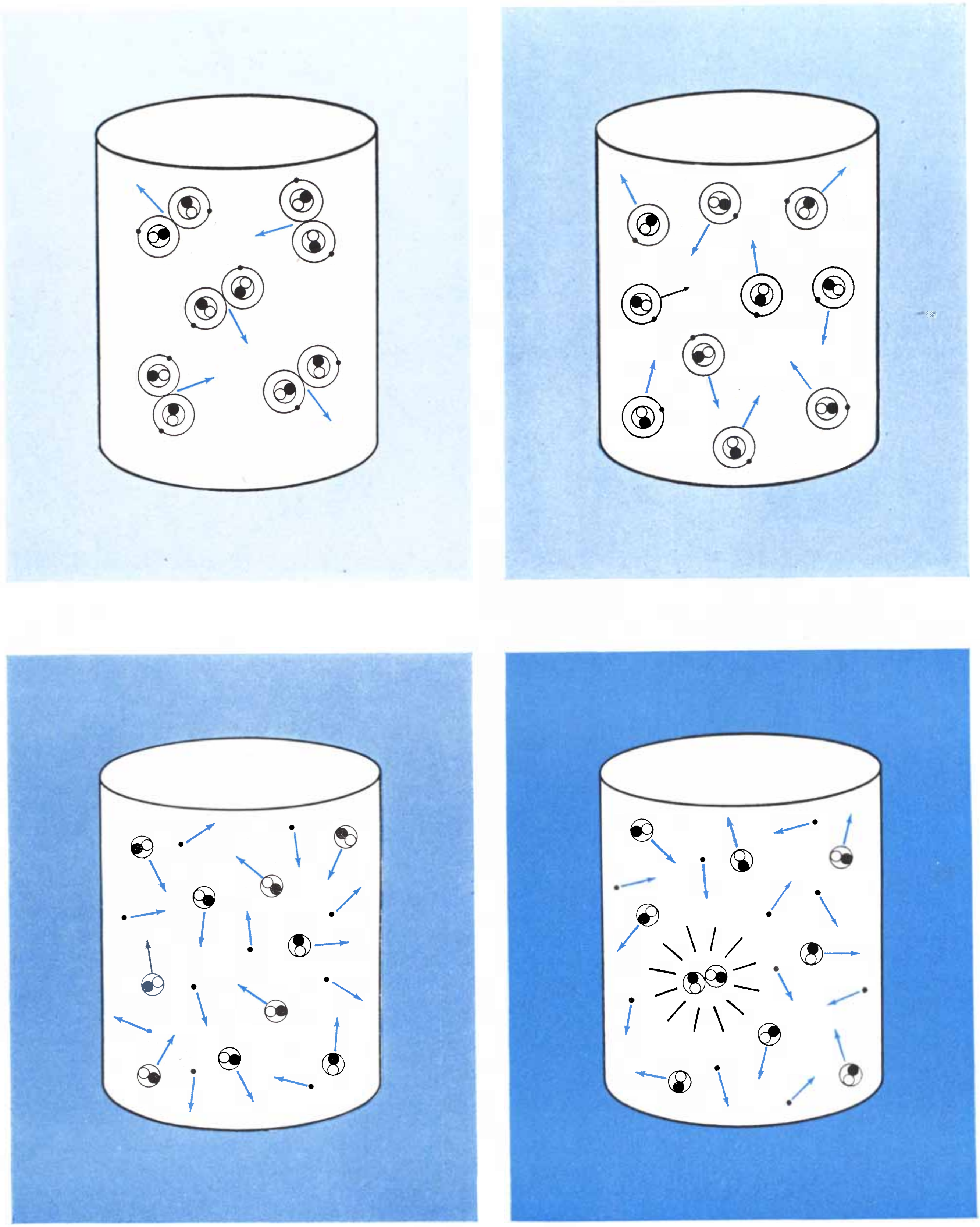
All this helps to explain the drive, if not race, to find out whether thermonuclear power can be tapped and put to work. If the fusion reaction can be made to yield power, it will solve forever both the fuel supply problem and the problem of radioactive wastes. The basic fusion fuel, deuterium, is as inexhaustible as the oceans, and fusion produces no appreciable amount of radioactive by-products.

The Fusion Reaction

Nuclear fusion is not exactly a new phenomenon. It has been generating the power of the sun and other stars for billions of years, and physicists discovered the fusion reaction in the laboratory before they did fission. But to create and control fusion power on the earth is a problem of a totally different order from harnessing fission. It is undoubtedly the most difficult project ever presented to scientists and engineers. This article is a report of the publishable progress made so far.

In the 1920s and 1930s physicists working with particle accelerators found that by accelerating protons (hydrogen nuclei) and other light nuclei to high enough energies (many thousands of electron volts) they could break through the nuclear electrical repulsion and force the projectiles to fuse with light nuclei in a target. The fusion releases energy, because part of the mass of the fusing nuclei is transformed into energy according to Einstein's famous equation $E=mc^2$. But in this sort of bombardment a great deal of energy has to be put in to make a few nuclei fuse. There can be no net yield of energy from fusion unless it proceeds by a self-sustaining reaction, as, for example, in the interior of the sun.

What is needed to produce a self-sustaining reaction? Here it is apropos to compare fusion with fission. The fission chain reaction is analogous to the explosion of TNT. A mechanical shock is sufficient to cause TNT to start exploding; the shock wave produced by fracture of its unstable molecules then touches off one molecule after another. Similarly in a fission chain-reaction the trigger for the successive fissions is supplied by neutrons, each fission releasing neutrons to attack more fissionable

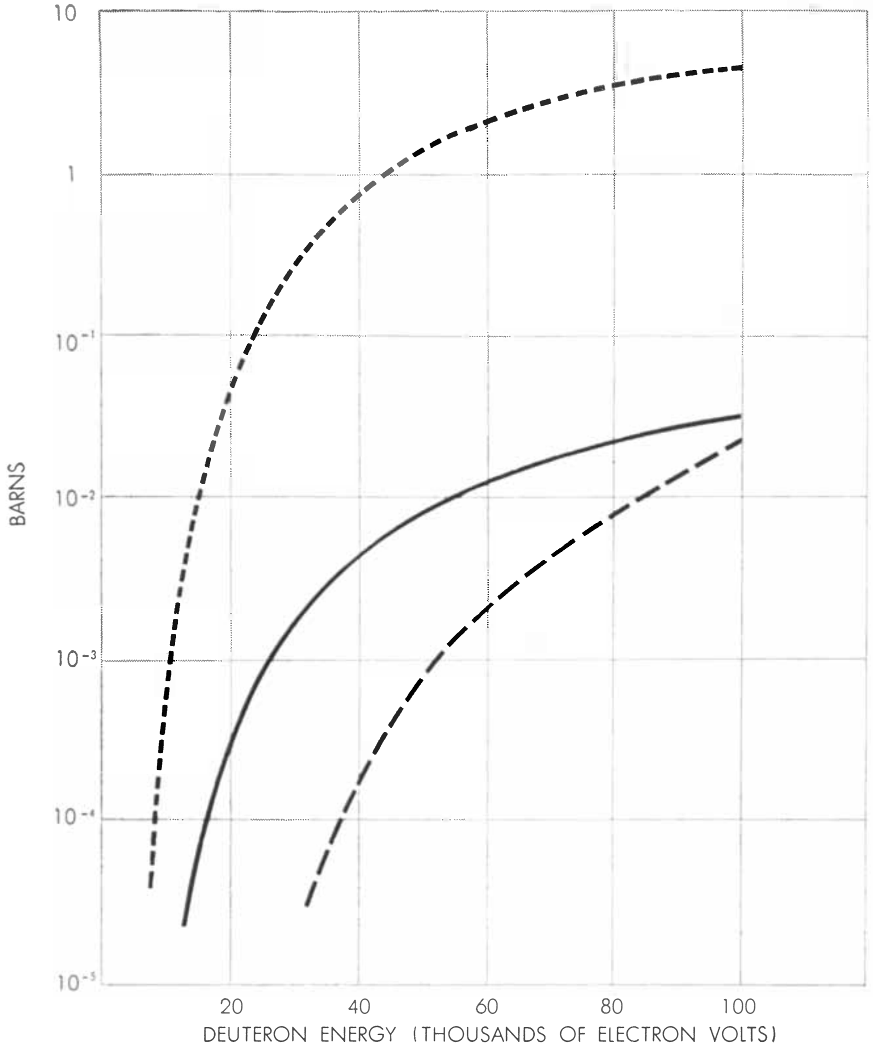


IMAGINARY EXPERIMENT shows the results of heating deuterium gas. At top left the gas is at room temperature and atmospheric pressure of 15 pounds per square inch. Heated to 5,000 degrees centigrade (*top right*), the diatomic molecules have split to form deuterium atoms and the pressure is 600 pounds per square inch. When the temperature is raised to 100,000 degrees (*bottom left*), atoms are ionized, forming a plasma of electrons and deuterons. The pressure is 20,000 pounds. At a temperature of 100 million degrees (and a pressure of 22 million pounds) some deuterons can fuse, releasing energy, but the reaction is still not self-sustaining.

uranium nuclei. In short, heat or kinetic energy plays no part in promoting the chain reaction.

A continuing fusion reaction, in contrast, is analogous to the familiar process of combustion. In ordinary burning, molecules combine (*e.g.*, hydrogen with oxygen, forming water), and their chemical reaction releases energy. To stick together or fuse, the molecules must collide violently, which means the material must be heated. Three conditions are needed to burn a chemical fuel and harness its heat to do work: (1) the fuel must be raised to its ignition point; (2) there must be enough of it to sustain a continuing reaction; (3) the energy released must be tapped in a controlled manner—*e.g.*, to heat water or to drive a piston. Now precisely the same conditions are needed to make a nuclear fusion reaction go and do useful work. The great difference is that for a fusion reaction the ignition point is rather high —hundreds of millions of degrees centigrade!

This one condition—the attainment of which was quite unthinkable on the earth until recently—underlies all our problems. From it stems a whole train of formidable questions. Unfortunately it seems that no one crucial experiment will tell us whether a solution is possible, as the first fission chain reaction did. We shall have to go through a long series of experiments to solve one problem after another. Most of them have to do with quantitative questions, that is, numbers. There never was a field in which the numbers were more imposing—or more important.



CROSS SECTIONS or probabilities of fusion reactions, as they vary with particle energy, are plotted for fusion of deuterium and tritium (*top*), deuterium and deuterium (*middle*) and deuterium and helium 3 (*bottom*). A barn is an area of 10^{-24} square centimeter.

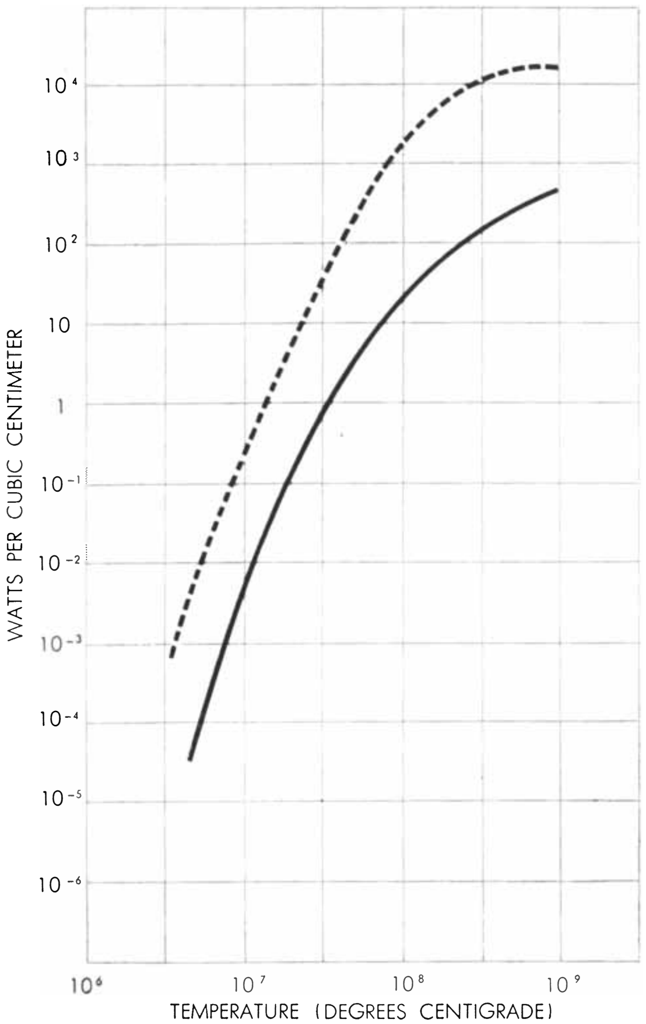
The Fusion Fuel

Our first concern is the fuel. The most interesting candidate is deuterium, a heavy isotope of hydrogen, found in ordinary water. The nucleus of the deuterium atom consists of one proton and one neutron. When two deuterium nuclei (deuterons) collide with enough energy to fuse, one deuteron grabs either the proton or the neutron of the other—the chances are 50-50. If it fuses with the proton (freeing the neutron), it forms helium 3, releasing about 3.25 million electron volts of energy. If it combines with the neutron (this time liberating its partner's proton), it yields about four million electron-volts and becomes hydrogen 3, or tritium, the radioactive isotope of hydrogen. A deuteron and a tritium nucleus (triton) will fuse more readily than two deuterons, and this reaction releases more energy. Tritium is therefore another potential fuel for thermonuclear reactors. It would have to be manufactured, however, as plutonium is, because there are only trace amounts of tritium in nature. One possible method of breeding tritium is to expose lithium to slow neutrons: on capturing a neutron, lithium splits into tritium and helium 4.

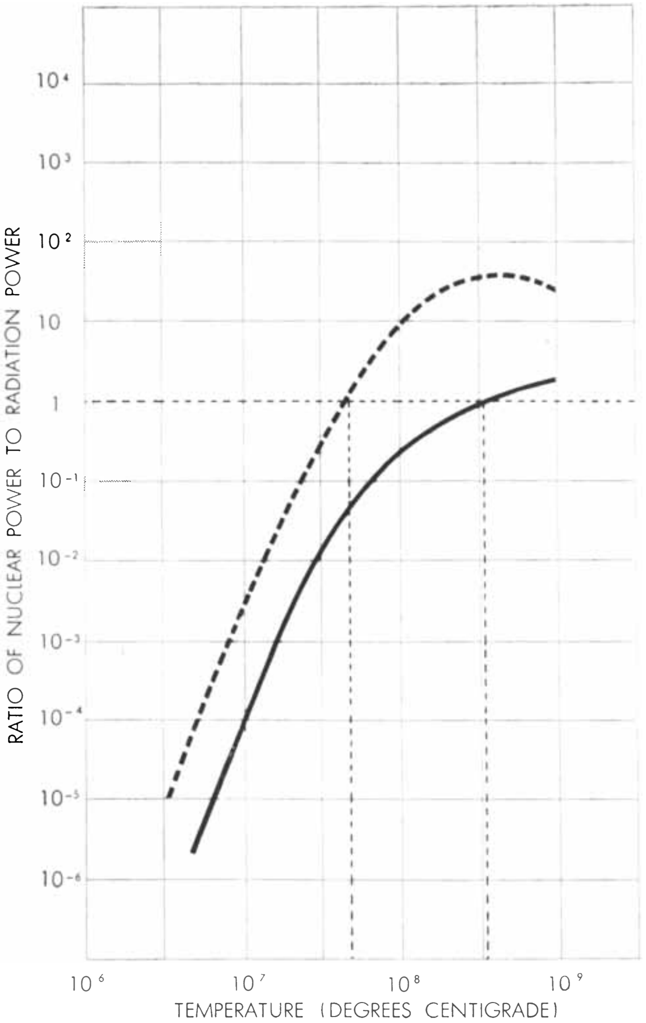
Complete "burning" of the deuterons and their products (tritium and helium 3) in a thermonuclear cycle would produce about seven mev (million electron volts) per deuteron burned. This corresponds to 43 million kilowatt-hours per pound of fuel. By comparison gasoline, one of the best chemical fuels, yields about six kilowatt-hours per pound. Although only a small fraction of the hydrogen in natural water is deuterium, still the deuterium in one gallon of ordinary water has an energy content equivalent to 350 gallons of gasoline! The oceans contain enough deuterium to supply the world with fuel for billions of years, even at a power demand 1,000 times the present figure. For use in our atomic energy program in the U. S., according to published figures, we are already producing an amount of deuterium which would be sufficient to supply the nation's total energy needs many times over if it could be burned as fuel. The cost of extracting deuterium from water is low enough so that deuterium would be less than 1 per cent as expensive as coal as a fuel. And finally, the nuclear burning of deuterium and tritium produces only inert gases, avoiding any problem of waste disposal.

Deuterium, then, represents the "ultimate fuel." But its great promise is matched by the equally great difficulty of finding a way to burn it!

The burning of thermonuclear fuel in an uncontrolled manner has been



FUSION-POWER OUTPUT of plasma at one ten-thousandth of atmospheric density is plotted against temperature. Upper curve is for deuterium-tritium fusion; lower curve, for deuterium-deuterium.



IGNITION TEMPERATURES, where nuclear power equals radiated power, are indicated by broken vertical lines for deuterium-tritium (*upper curve*) and deuterium-deuterium (*lower curve*).

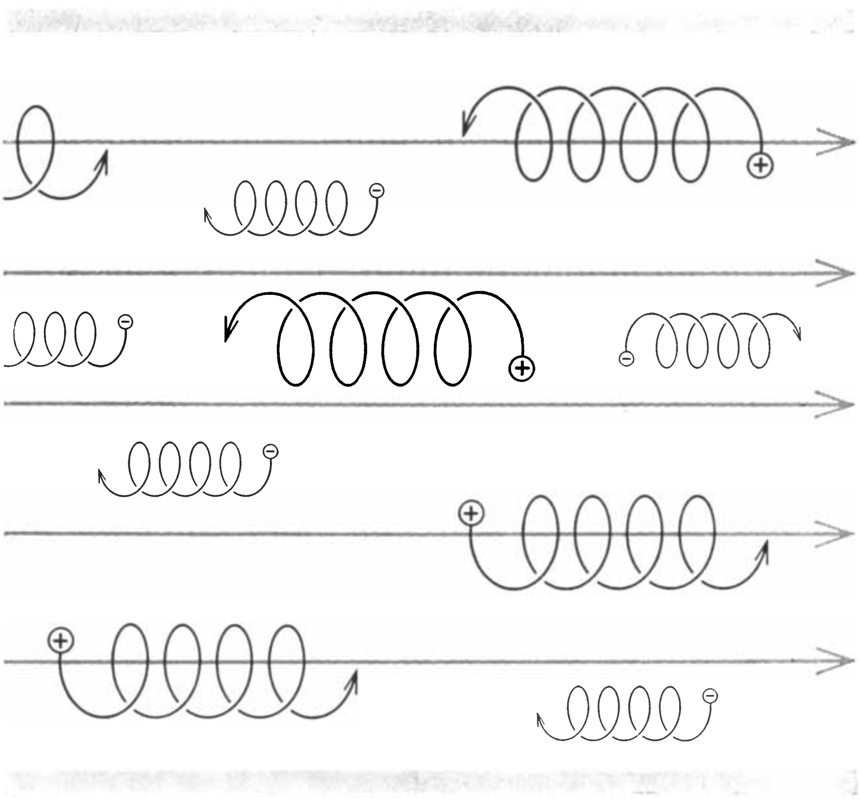
achieved with all too well known success in the hydrogen bomb. But the problem of producing a controlled fusion reaction is quite different. Let us see what the necessary conditions are. The best way to do this is to follow an imaginary experiment.

The Plasma

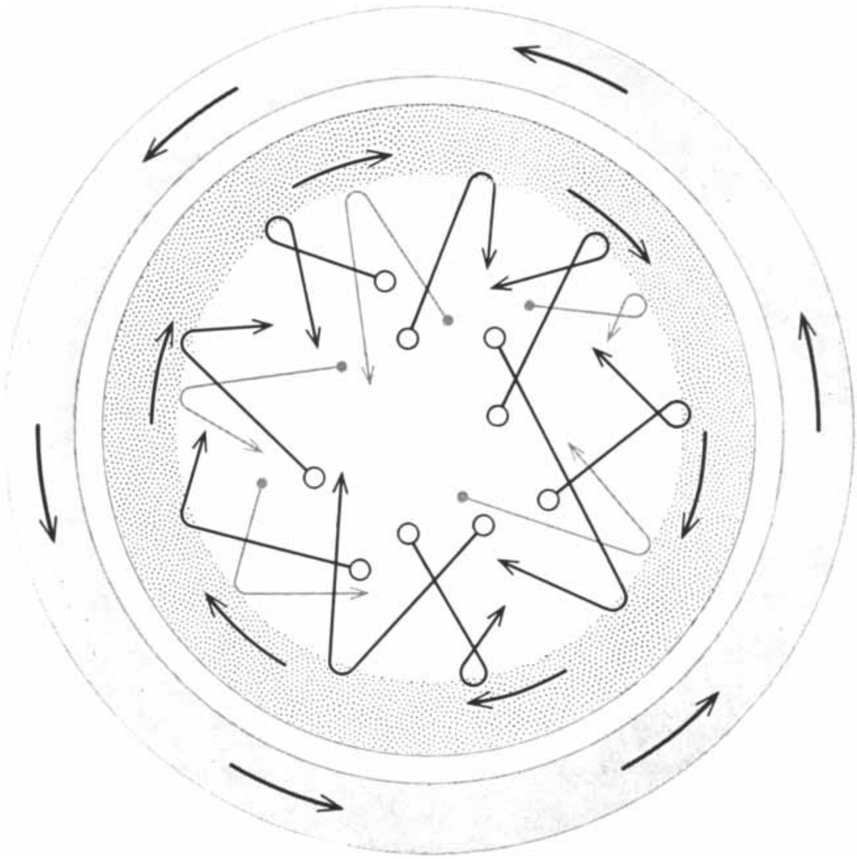
We take a liter of deuterium gas confined in a vessel made of a mythical material which is capable of withstanding the enormous temperatures and pressures that will arise in the course of the experiment. At room temperature and normal atmospheric pressure the deuterium gas-molecules are wandering about in the vessel with an average kinetic energy of about one 25th of an electron volt, or a velocity of about 3,000 miles per hour. Of course no fusion reactions are taking place. Now we heat the gas to 5,000 degrees C. At this temperature we no longer have molecules: the violence of their collisions has broken them apart into deuterium atoms. The pressure has risen to about 40 atmospheres (600 pounds per square inch), and the average velocity of the atoms is about 40,000 miles per hour. But we are still very far from the velocity needed to make two nuclei fuse.

Next, let us jump to 100,000 degrees. The remarkable properties of the mythical wall material are very much needed now, for any real material would long since have vaporized. Now the deuterium atoms of the gas have been broken down to the electrically charged nuclei (deuterons) and electrons: in a word, the gas has become what is known as a plasma. The gas pressure has risen to 1,500 atmospheres. The average velocity of the electrons is 10 million miles per hour, and even the much heavier deuterons are moving at the great speed of 170,000 miles per hour. Yet the deuterons still do not have sufficient energy effectively to overcome their mutual electrostatic repulsion. At this temperature there would be only about one fusion in the liter of plasma every 500 years! We still have a long way to go before we shall reach the ignition temperature of a mass of deuterons.

At one million degrees, the rate of fusion reactions will increase more than a billion billion times, but the total energy output will still be too small to be detected—only a few millionths of a watt per cubic centimeter. At 100 million degrees, however, the reaction rate will become really respectable. The pressure then will have reached the staggering value of 1.5 million atmospheres. The electrons will be traveling at 90,000 miles per *second*, and the deuterons at 1,500 miles (around the world in 16



PATHS OF PLASMA PARTICLES in a magnetic field are helixes. Positive particles go counterclockwise; negative particles, clockwise looking in the direction of the field.



PLASMA IS CONTAINED by a magnetic field (*dotted ring*) which prevents escape of particles. Outer arrows show current in coil; inner arrows, current from deflected particles.

seconds). Essentially all of the deuterons will react with one another rapidly (within a fraction of a second), and their reactions will release energy at a fantastic rate—about 100 million kilowatts. But we shall not yet have arrived at the kindling point: to sustain the reaction we shall still have to put in more energy than the fusions release. Only at about 350 million degrees will the "fire" (*i.e.*, thermonuclear reaction) become self-sustaining.

This imaginary experiment brings out several important points. First, we need extremely high temperatures, though when we speak of high temperature here we are not thinking of heat in the usual sense but of the kinetic energy of the gas particles. Second, we could not even think of using the fuel at ordinary gas concentrations. If we are to keep the energy output and pressure of the gas within controllable bounds, we must start with a thin gas at a density much lower than at atmospheric pressure—somewhere in the neighborhood of one 10,000th of an atmosphere. But what a thin fuel this is! In a laboratory a gas at this density would be considered practically a vacuum.

One of the interesting consequences of using a very low density is that even though the plasma is very hot in terms of the speed of its particles, its heat *content* will actually be very small. A liter of deuterium plasma one 10,000th of an atmosphere in density would, at a kinetic temperature of 350 million degrees, have a heat content amounting to 18,000 calories—about enough to heat a small cup of coffee.

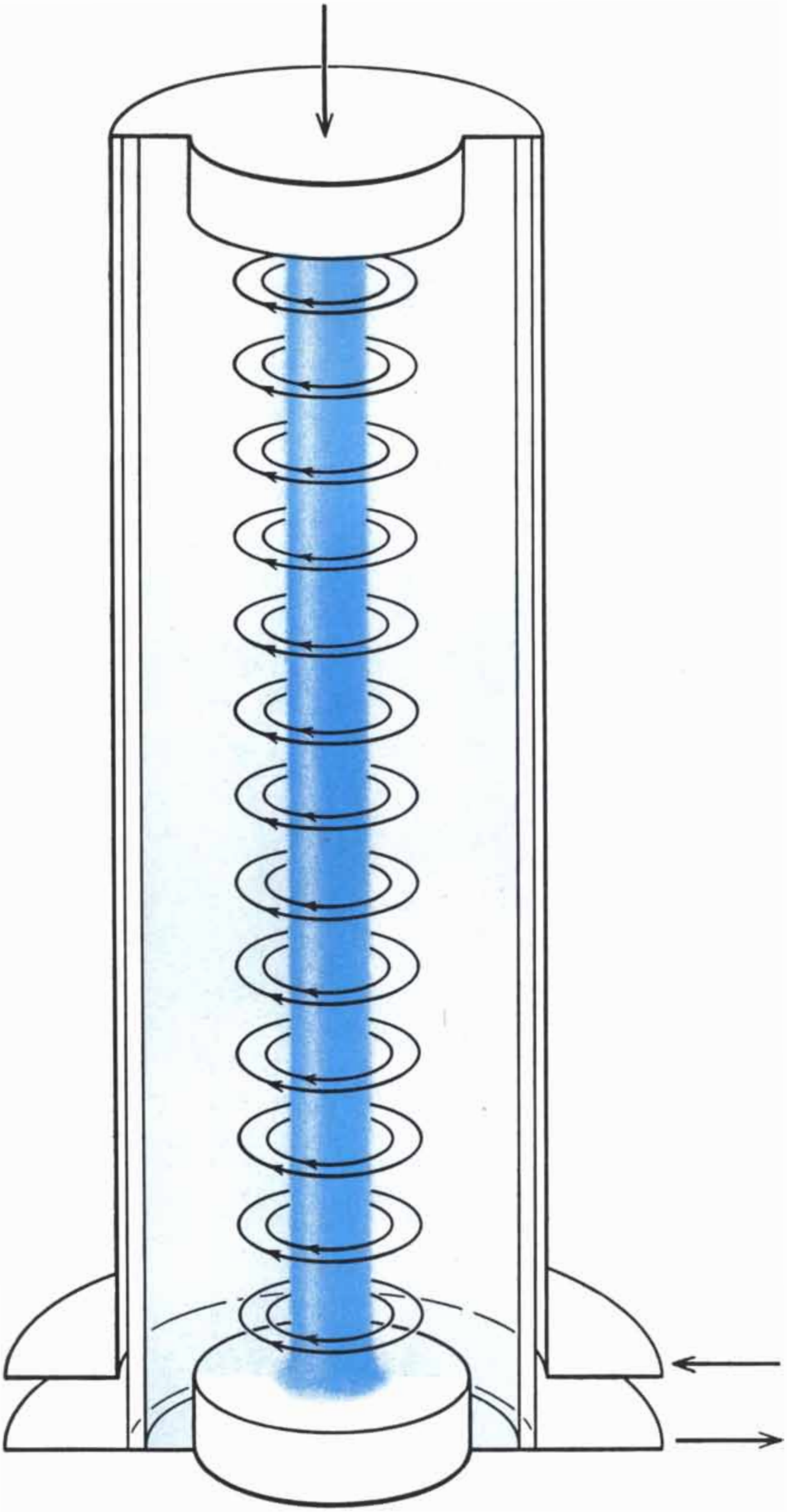
To calculate the rate of fusion power production from a hot plasma it is only necessary to know the reaction cross sections and to insert these as data in the theory of thermonuclear reactions in a hot gas [*see charts on page* 77]. However, calculations of this kind, important as they are in specifying the required physical conditions, shed no light on *how* to heat a gas to thermonuclear temperatures or on whether the reactions, once initiated, could be made self-sustaining. This latter question depends on how much of the energy will be lost by radiation and other mechanisms. In the sun, the energy generated within its huge volume is sufficient to maintain the reactions in spite of the radiation loss from the surface. If we could build a fusion reactor as big as the moon, we would not need to worry particularly about energy losses. But for a reactor of practicable size this is our key problem.

Let me first mention the unavoidable

losses that must be lived with. These are the losses by radiation from the plasma—primarily in the form of X-rays emitted when electrons collide with nuclei. Now at a temperature of 100 million degrees, one cubic centimeter of dense matter would radiate energy at the unbelievable rate of three million million million kilowatts! But fortunately the rate of radiation drops very rapidly as the density of the matter falls. At the low density we have been considering, the radiation loss becomes comparatively small. The energy yield of fusion reactions increases rapidly with rise in temperature, and it will outstrip radiation losses at a temperature above 50 million degrees in the case of the deuteron-triton reaction and above 370 million degrees in the deuteron-deuteron reaction. These, then, are the ignition temperatures of the respective fuels. But the plasma must be very pure, because nuclei of higher elements (above hydrogen and helium) greatly accelerate the rate of radiation. A surprisingly small amount of impurities could poison a very large volume of plasma. For example, the metal in the head of a pin, if vaporized, would be quite sufficient to poison several railroad tank cars full of plasma. It is clear that purity will be a prime requirement in any controlled-fusion reactor.

Of the other class of energy losses—the ones we can and must reduce—the most serious is dissipation of particle energy to the walls of the reactor. We have to have a closed chamber, to hold out the atmosphere and keep our gas at low density. But consider the particles in this gas. They are so widely dispersed in our near-vacuum that each deuteron, in its random wanderings, travels thousands of miles on the average before it encounters another deuteron (or a triton). It has a far greater chance of hitting the walls of the container first. Yet if it does, this collision will immediately damp its energy. Obviously we cannot allow the particles of the plasma to touch the walls. Contrary to a common impression, the reason is not that the plasma will vaporize the walls (it does not contain much heat) but simply that contact with the walls would instantly cool the plasma and quench the reaction.

This, then, is the nub of the problem: How to confine a very hot gas within a material chamber (for at least a fraction of a second) without allowing any appreciable amount of it to reach the chamber walls. Posed in this way, it sounds like a science-fiction problem, quite unsolvable in any real world. But



PINCH EFFECT occurs when a large electric current is sent through a plasma in a cylinder. Circular magnetic lines of force set up by the current contract and pinch the plasma into a narrow channel (*colored column*). The straight arrows show the direction of the current.

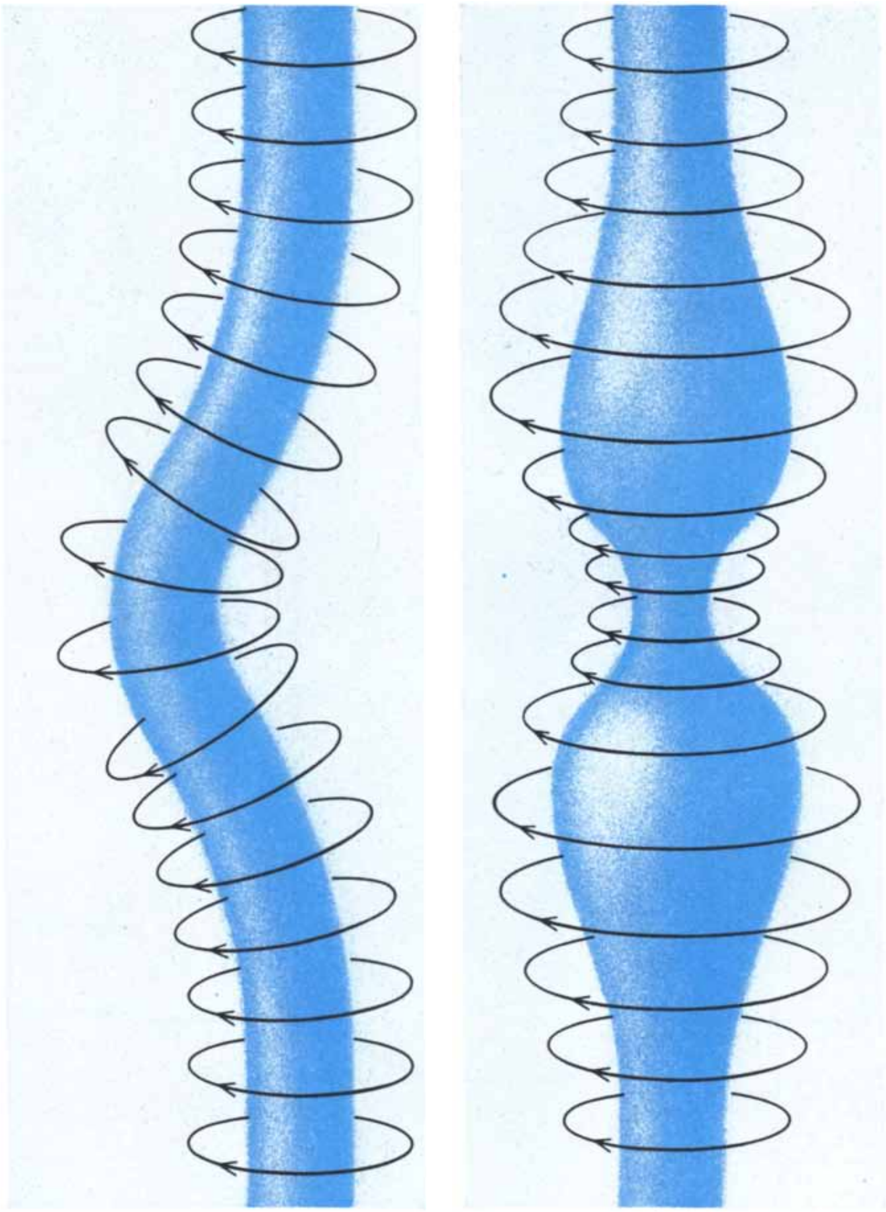
as is now well known, about a decade ago an ingenious solution emerged—namely, the plasma might be confined within a magnetic field, serving as a kind of furnace liner in the chamber to keep the particles away from the walls.

The Magnetic Bottle

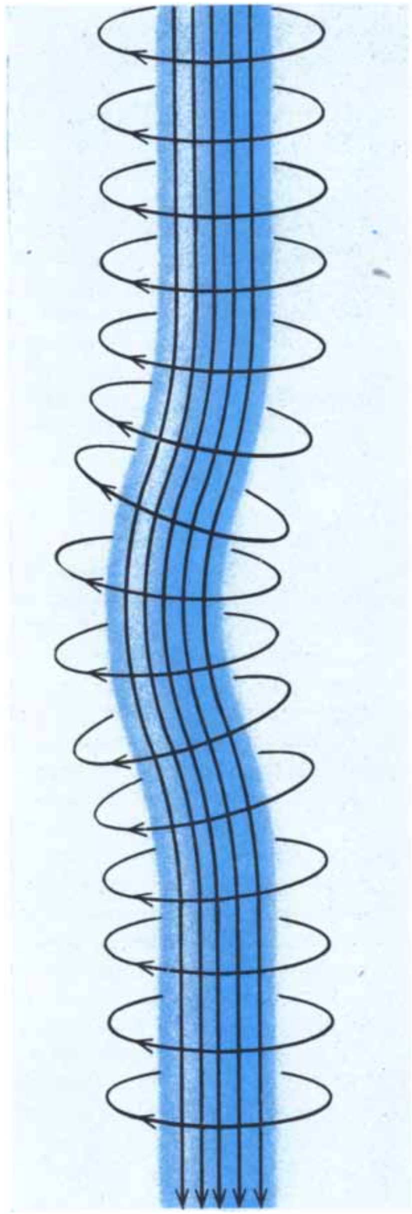
The idea rests basically on the simple fact that a strong magnetic field will deflect charged particles from a straight path [*see diagram at top of page 78*]. Now a hot, high-pressure plasma could, under the proper circumstances, generate an internal magnetic field of its own strong enough to exclude the externally applied field. Inside such a plasma the particles would therefore move in straight lines. But at the boundary of the plasma they would be deflected back into it by the outside magnetic field [*see diagram at bottom of page 78*]. The magnetic lines of force, acting like elastic rubber bands, could resist considerable pressure. If the magnetic field were made strong enough, it should form a magnetic "wall" able to contain a high-pressure plasma, just as a steel cylinder holds a high-pressure gas. According to the theoretical calculations, a field with a strength of 50,000 gauss, for example, could withstand a plasma pressure of 100 atmospheres, and a field 10 times stronger (which has been achieved in laboratories) could support a pressure of 10,000 atmospheres.

A fusion reaction sustained in such a magnetic bottle could never "run away," as the fission chain reaction may. If the plasma pressure became stronger than the magnetic field, it would rupture the magnetic wall and the plasma would touch the material chamber wall, which would immediately quench the fusion reaction. By the very nature of the beast, then, a fusion reactor could never explode; it could only collapse.

The simplified picture we have been considering should not be taken to mean that the magnetic bottle would be leakproof. Actually the plasma and the magnetic field would gradually penetrate and intermingle with each other, and the plasma would eventually escape completely unless replenished. Fortunately this leakage should be slow



INSTABILITIES in a pinched plasma arise from kinks (*left*), where the magnetic lines are crowded on the concave side, and constrictions (*right*), where the field is also crowded.



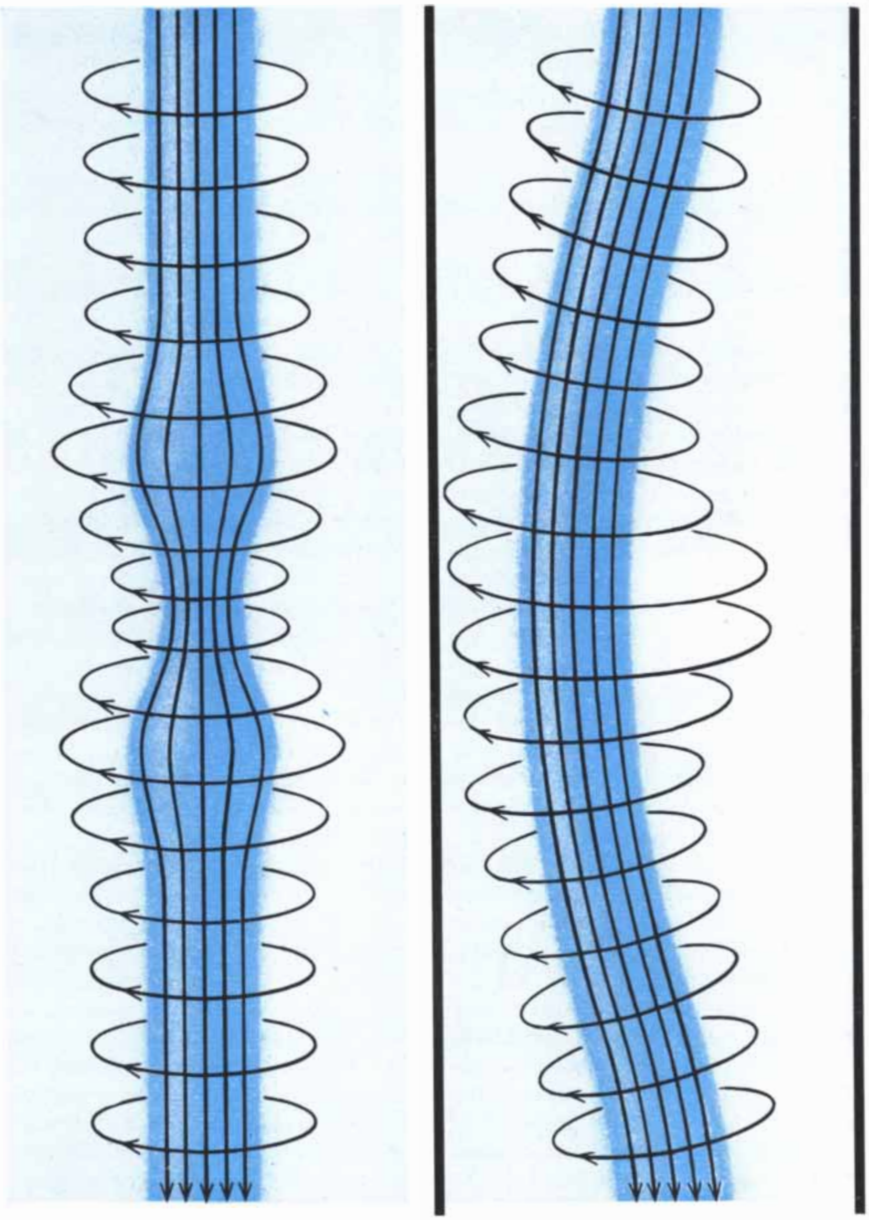
STABILIZED PINCH might be achieved by putting a magnetic field (*long arrows*)

enough, according to the theory, to permit the achievement of a self-sustaining fusion reaction. But, as we shall see, a magnetic bottle does not always behave as the simple theory predicts. The interactions between a high-temperature plasma and magnetic fields are a difficult problem in fundamental physics, and they have given rise to a new field of study which might be called "experimental astrophysics."

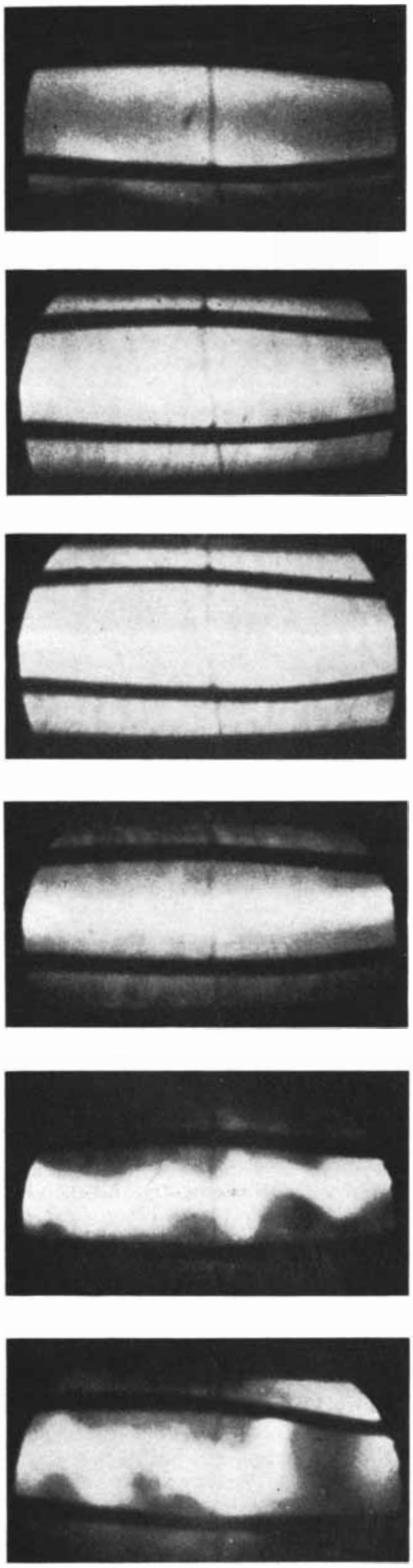
The Pinch Effect

So much for the theory. How could we actually make a magnetic bottle? It occurred independently to many investigators that an obscure electrical phenomenon known as the "pinch effect" might provide the answer. This effect, first produced experimentally only about a decade ago, requires a very large electrical current. When such a current is passed through a conducting gas in a tube, it sets up a magnetic field which tends to pinch the gas and pull it away from the tube walls [*see diagram on page 79*]. The magnetic lines of force circling the gas compress it by their tension. Since a plasma is an excellent conductor of electricity, the pinch effect looked like an attractive and ready-made means of forming a magnetic bottle.

Theoretical calculations showed that it would take a very large current indeed—millions of amperes—to confine a plasma of high temperature and low density. Not discouraged by this fact,



through a plasma. Tension would straighten kinks (*left*) and mutual repulsion would resist constrictions (*center*). Circular lines hold plasma away from conducting wall (*right*).



LIFE OF A PINCH is depicted in this series of image-amplifier photographs. The top three pictures show the formation of the pinched column of plasma (*bright band*) as current is sent through the gas. The remaining views show its death, brought on by the development of kink instabilities.

investigators in many countries carried out experiments with simple pinch tubes [*see illustration on page 73*]. They applied a high voltage to a low-pressure gas in an insulated tube and produced an electrical discharge. This ionized the gas, and heavy current then began to flow. As they hoped, the pinch made its dramatic appearance. But with it also came a blow to their hopes. The pinch lasted only a millionth of a second or so; no sooner had the column of plasma been compressed than it writhed violently and drove itself to the tube wall. Furthermore, the tighter the pinch, the faster it destroyed itself.

This was not hard to understand, and in fact was predictable theoretically. Two different types of instability can develop. In the first place, any small kink in the pinched column will grow rapidly, because the magnetic pressure is stronger on the concave side of the kink (where the lines of force are crowded together) than on the convex side [*see diagram at left on page 80*]. The second cause of instability is a kind of "sausage" effect [*middle diagram on page 80*]. The plasma tends to pinch or neck itself off at one or more points along the column, and thus cuts itself into pieces.

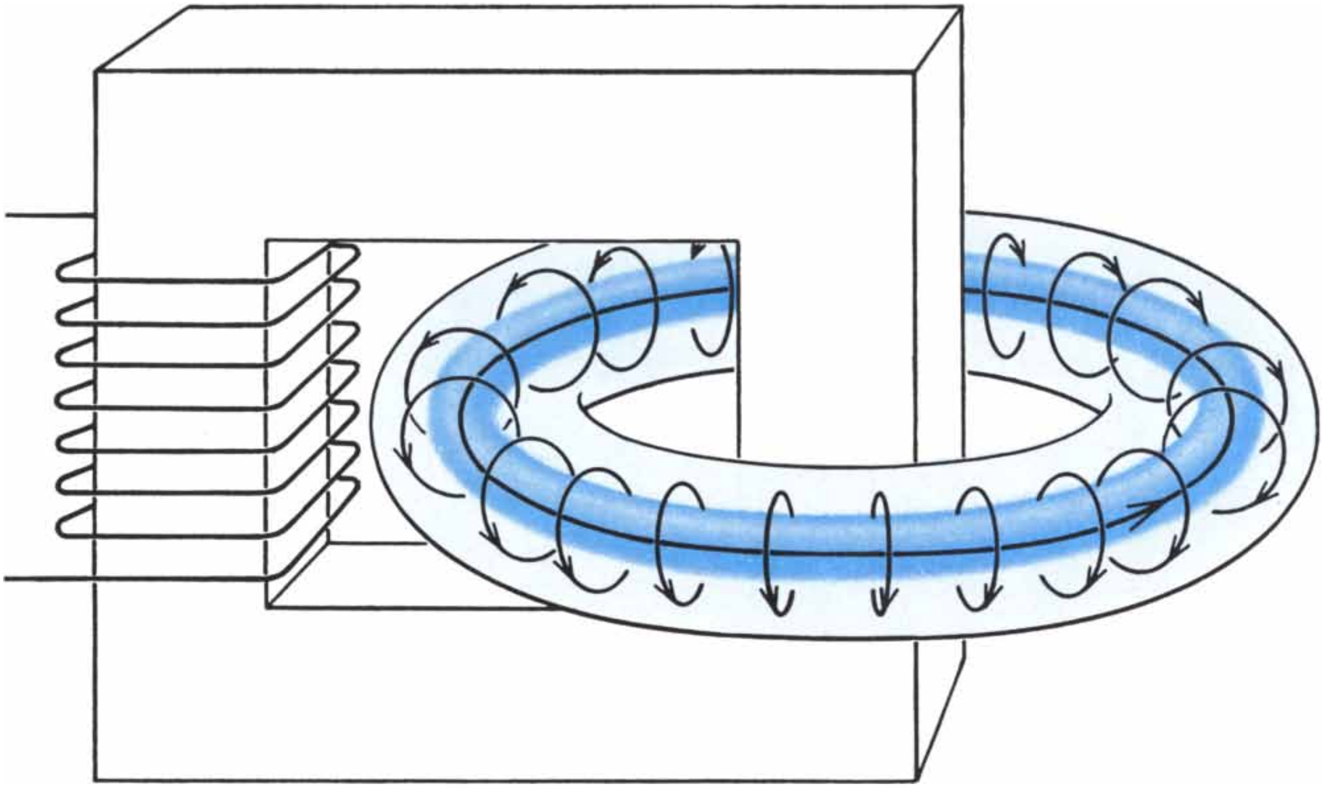
Incidentally, in connection with the latter phenomenon there is an interesting story which illustrates how hopes can suddenly rise and just as suddenly fall in an important but uncharted field of research such as the fusion power enterprise. When investigators first produced strong pinches in deuterium gas, they were delighted to discover bursts of neutrons—evidence of fusion reactions in the plasma. They thought they had reached thermonuclear temperatures momentarily. But on analysis they had to conclude that it was merely some obscure electrical effect, associated with the violent disruption of the pinch by the sausage instability, that had accelerated a few deuterons to fuse.

How could the pinch be stabilized? Theoretical investigations published in the U. S., in the United Kingdom and in the U.S.S.R. have suggested a possible answer, although they have not yet shown how the physical conditions necessary to make it work could be achieved. The idea is to create not only a pinching magnetic field around the plasma but also a strong longitudinal magnetic field *within* the plasma column [*see diagrams on pages 80 and 81*]. The internal field would act as a kind of stiffener. If a kink started to develop, it would tend to stretch the interior lines of force, and their elastic resistance would pull out the kink. Similarly if the sausage type of constriction tried to pinch into the column, the internal lines of force would resist being squeezed together and thus would prevent collapse of the column.

There is a third type of instability which could destroy a plasma column: namely, a long, gentle bend of the column that would grow in strength and push the column to the chamber wall [*see diagram at right on page 81*]. However, this could be counteracted by using a conducting material for the walls of the tube. Since a conductor acts as a barrier to a magnetic field, the magnetic field lines around the plasma column would be crowded against the wall where the bent column approached it, and the resulting back pressure would push the column back toward the center of the tube.

I should make clear that the straight pinch columns illustrated here are simplified systems which merely exemplify the principles. In practice it would probably not be desirable to try to produce a stable pinch in a straight tube, for several reasons: among other things, the electrodes at the ends of the tube would have a cooling (*i.e.*, quenching) effect on the plasma. Pinch experiments have already been performed with other shapes. One of these is a doughnut-shaped tube in which currents are induced and can circulate without bumping into a solid surface. A high voltage applied to the winding around a large iron transformer core in the tube produces an electrical discharge in the gas, which then functions as a one-turn secondary winding. Very heavy currents can be induced into the plasma in this way.

Besides the pinch effect, other possible methods of forming a magnetic bottle are being investigated, in the U. S. and no doubt in other countries. Most of the current research on the fusion power problem involves experiments in very complicated electromagnetic phenomena—the behavior of a high-temperature plasma in various magnetic field configurations. It is extremely hard work, taxing all the resources of our present technology. As I have mentioned, there is little likelihood of anything like a sudden "break-through" to a radically simpler approach. Since we shall make headway only by many mutually reinforcing studies and by the development of new and unusual techniques, it is evident that progress would be more rapid if the various nations involved joined



DOUGHNUT-SHAPED PINCH TUBE is made by threading a transformer core through a hollow ring containing plasma. Current through the winding at left causes a strong induced current in the plasma, which is then pinched by its own circular magnetic field.

in a cooperative exchange of information on all phases of the research.

Tracing the Wisp

We are having to learn for the first time how to handle and manipulate rapidly huge quantities of electrical energy, and to build big, extremely clean vacuum systems. One of the thorniest problems is measurement. It is hard enough to create a hot plasma in the first place, but to find out what it is doing, once created, is sometimes still harder. Some new measurement techniques have already been developed. To measure the density of a plasma there is a new "microwave interferometer" using beams of millimeter radio waves as probes. The temperature of the plasma is assessed by studying its X-ray emissions, its radio "noise" and its escaping particles or reaction products. Somewhat surprisingly, a very hot plasma emits little visible light. But it has been possible to make spectroscopic studies of cooler plasmas, in which the atoms are not completely stripped of their electrons. These measurements not only indicate the temperature but also tell the velocity of the plasma's motions, by the Doppler shift. And simply by measuring changes of the magnetic field during an experiment we can get information about the temperature, density, shape and velocity of plasmas as they are formed.

To appreciate the observation problem you have to picture the scene of the events we are studying. Most of the experiments on high-temperature plasmas are carried out within antiseptic vacuum systems surrounded by conductors carrying large and rapidly varying electrical currents. And what we have to detect are the whims of an invisible, short-lived wisp of near-nothingness somewhere in the bowels of this apparatus!

Tapping the Power

Plainly it will be several years before any fusion reactor is developed to the point where we have to face the final problem of extracting its power. But of course some thought has already been given to this matter.

If the fuel is a mixture of deuterium and tritium, the lion's share (80 per cent) of the energy released by the fusion is carried off by the neutron emerging from the reaction. This energy would be tapped by trapping the fast neutrons and feeding the resulting heat to a steam system generating electricity in the conventional way. Since such a reactor would have to breed more tritium, the neutrons would probably be trapped in a breeding blanket of lithium surrounding the reactor. Some of the electrical power generated would have to be fed back to the reactor to maintain the magnetic bottle.

If the fuel is deuterium alone, we have the intriguing possibility of turning the energy output directly into electricity. In the deuteron-deuteron fusion, 66 per cent of the energy released is imparted to the charged reaction products —helium nuclei and protons. It is quite possible that conditions could be arranged so that most of these particles stayed trapped within the plasma. In that case the heated and expanding plasma would tend to push outward against the magnetic field, and by the use of properly arranged circuits this motion could in principle be made to generate a current. In other words, in pushing against the magnetic field the expanding plasma would do work, just as steam expanding against the piston of a steam engine does work. In the case of the plasma the piston would be the "wall" of the magnetic field, and the linkages converting its energy into useful work would be electrical circuits instead of rods and wheels. It is possible that the efficiency of this engine might be much higher than that of the conventional steam cycle, for the thermodynamic principles that limit the efficiency of ordinary heat engines would not apply.

In the last analysis the feasibility of fusion power probably will hinge primarily on the size of the reactor. Very likely many potentially workable reactor schemes will have to be rejected on the basis that they would be impracticably large. On the other hand, "pocket-edition" fusion reactors are simply out of the question, on theoretical grounds. The fusion power plants of the future, if they are ever realized, will in all likelihood be large central stations for generating electrical power.

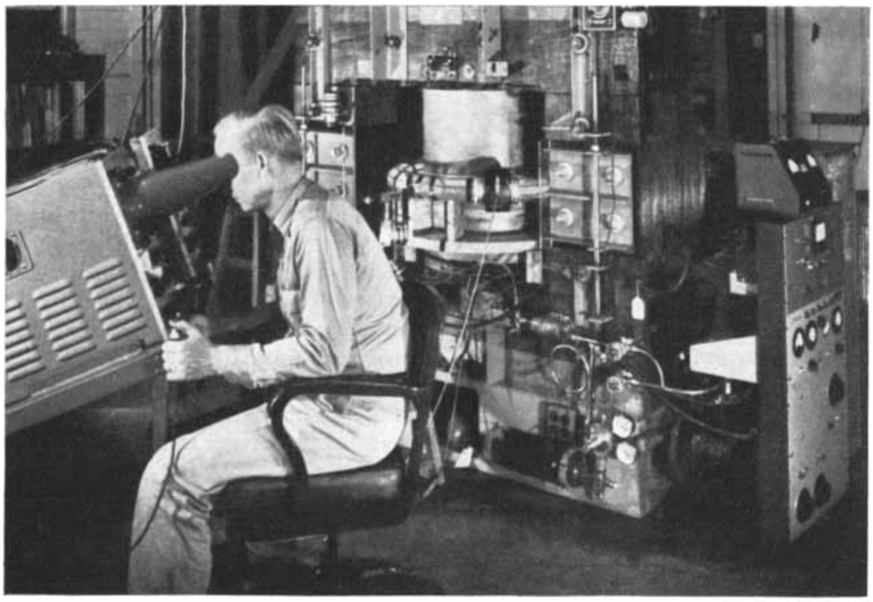
Growing Hopes

The scientists working on the fusion power project in the U. S. confidently believe that all the problems will eventually be solved, for, difficult though the problems are, they now see no really fundamental barrier standing in the way of ultimate success.

I want to mention a few of the milestones that have been passed, insofar as secrecy restrictions permit. The first group to consider the possibility of obtaining fusion power through the magnetic confinement of a hot plasma, so far as we know, were Enrico Fermi, Edward Teller, James Tuck and others at the Los Alamos Scientific Laboratory. Although they advanced their ideas around the end of World War II, no extensive experimental work was started in the U. S. until about 1951, when programs began under Tuck at Los Alamos and Lyman Spitzer at Princeton. Scientists in the United Kingdom apparently had launched some work two or three years earlier, and the U.S.S.R. may have started about the same time. In 1952 the U. S. Atomic Energy Commission sponsored a large conference on controlled-fusion reactions. In the same year a program was initiated by Herbert York at the University of California Radiation Laboratory in Livermore. Smaller programs have since been set up at the Oak Ridge National Laboratory and New York University. Within the past year two substantial programs have been initiated with private capital: at the General Atomics Laboratory in San Diego, Calif., and at the General Electric Research Laboratory in Schenectady, N. Y.

Among other countries known to be engaged in studies of controlled fusion are France, Germany, the Netherlands and Sweden. It is abundantly evident that the search for fusion power is taken seriously in all parts of the world. The nature of the problems being faced, the time it will no doubt take to solve them, and the importance of the goal to be won are compelling reasons to hope for the growth of international cooperation in the research.

If the reader of this article is left with the impression that the search for fusion power is at once the most fascinating, the most difficult and potentially the most important peacetime scientific effort ever undertaken, he will be sharing the opinion of the many scientists now working on this problem.



THE "PERHAPSATRON," an instrument for producing the pinch effect in a plasma, was photographed at the Los Alamos Scientific Laboratory. Doughnut tube is in the center.

Left: A 9-pound mold of electroformed copper for a 21-inch doll. Soft vinyl "skin" (center) was withdrawn through neck opening. Finished doll at right.

How a new kind of copper keeps little girls happier

Doll heads also are cast inside molds of electroformed copper – like that shown at left above.

THE PROBLEM: Little girls are fussy. Dolls must have carefully modeled features, toenails, and fingernails – have skins that feel soft and smooth. So most doll bodies and heads are now formed of velvety-smooth vinyl plastisol, cast in precision, one-piece copper molds.

Making molds is tricky. The Plastiplate Co., South River, N. J., a leader in the field, does it this way. A wax or vinyl master model of a doll gets a thin, conductive coating of silver. Then copper is built up on the silver in an acid-copper electroplating tank to form a shell about one-eighth inch thick. When the model is removed, the copper shell becomes a one-piece doll mold. With ordinary copper anodes, great care was required to make sure that molds were uniformly accurate in detail – that they could stand the strains of production in automatic casting machines.

THE SOLUTION: Two years ago, Plastiplate tried out "Plus-4"® (phosphorized copper) Anodes in one electroplating tank. The molds from this tank were superior in uniformity, strength, and toughness. The deposit was better on hard-to-reach surfaces, demonstrating the greater "throwing power" of "Plus-4" Anodes. Scrap was cut and tank maintenance simplified. Now all of Plastiplate's tanks are supplied with "Plus-4" Anodes.

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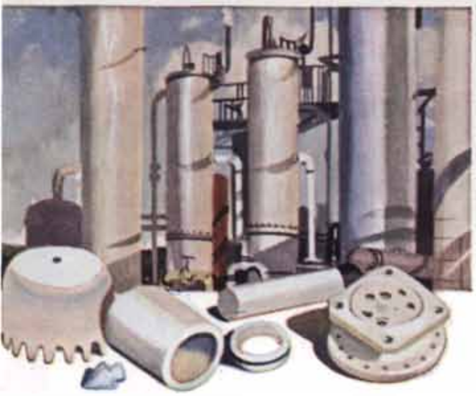

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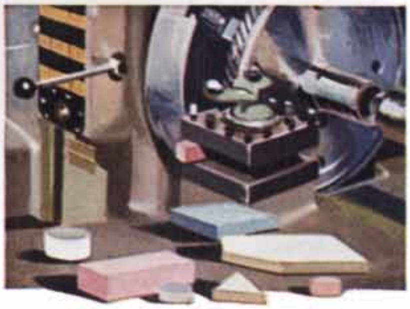

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Neanderthal Man

It is known that this large-boned man and Homo sapiens lived at the same time. The author presents a hypothesis on where the two kinds of men originated and how they came in contact

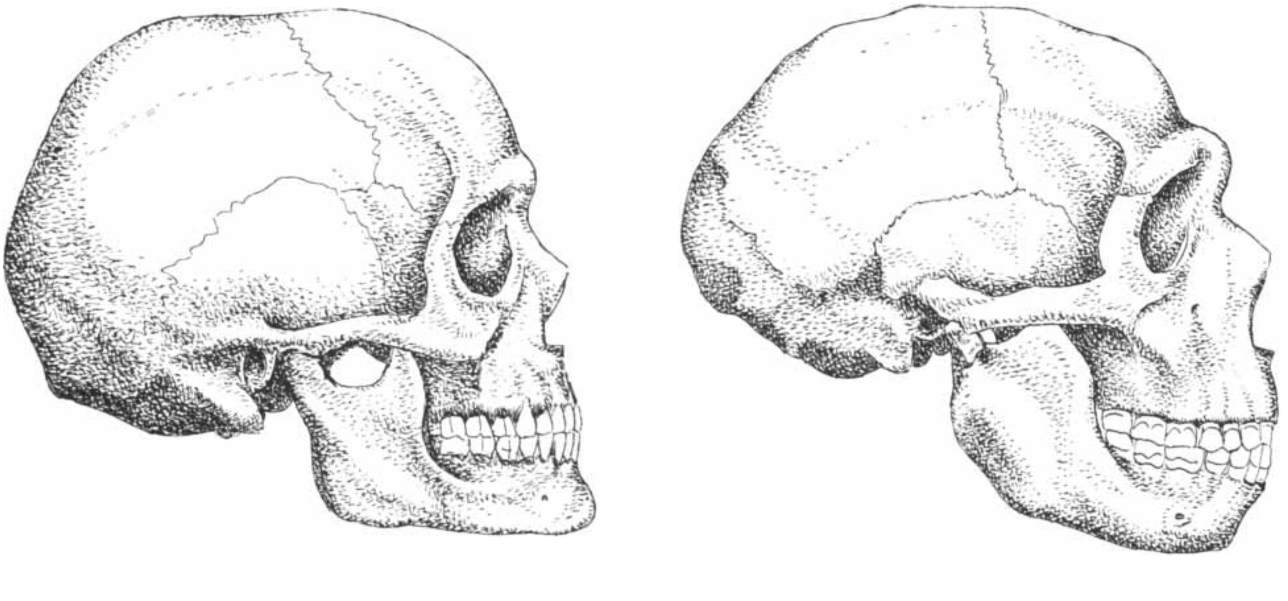
by J. E. Weckler

Dozens of fossil skulls, unearthed in various parts of the world, tell us that man came into existence at least half a million years ago. But the fossils leave us mystified about his beginnings. Long study of the skulls has failed to give any conclusive picture of man's early evolution; in fact, many of the theories have not stood the test of new fossil finds. Among all the enigmas, Neanderthal man, whose bones were first discovered in a cave in Germany just 100 years ago, is still perhaps the most puzzling. Just what kinship does that extinct human creature bear to our own species, *Homo sapiens*? Neanderthal and *sapiens* both roamed the earth 100,000 years ago. Did their paths cross? Why did Neanderthal perish and *sapiens* inherit the earth?

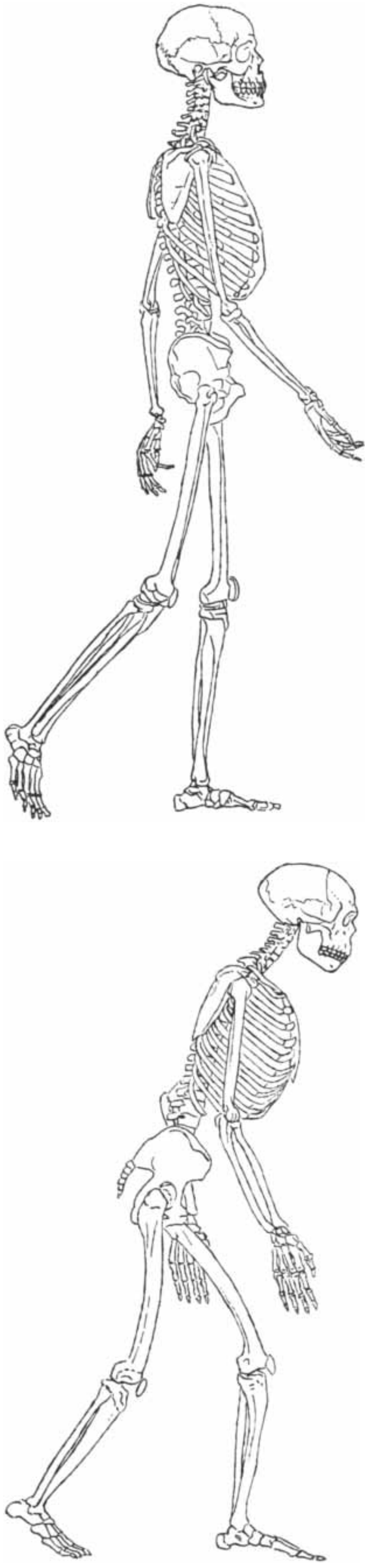
Although the bones themselves do not throw much light on these questions, I believe that they do fall into a meaningful pattern when we consider the world in which the early men evolved. This article presents a theory based on a global view of the earth at that time—particularly the climate and geography.

The scene of man's emergence from his animal ancestry was the Old World of Europe, Asia and Africa: it is in that part of the earth that all the ancient fossils of man and manlike creatures have been found. Now looking at the great land mass of the three joined continents, we can see it divided into two worlds, separated by a gigantic geographical barrier. The barrier is the belt of mountains, high plateaus and inland seas cutting across the middle of Europe and Asia, from the Black Sea to China. On one side of this barrier lies central and eastern Asia. It is separated from southern Asia (*e.g.*, India and Asia Minor) by the topography, and from northern Europe by the barrier of great distance. Even in historic times eastern Asia has been a world apart from Europe and the Middle East.

Geographically, then, the Far East was one world and Europe, southern Asia and Africa formed another. Although Europe and Africa may seem sharply separated by the Mediterranean,



SKULLS of *Homo sapiens* (*left*) and Neanderthal man (*right*) are compared. The *Homo sapiens* skull is that of Cro-Magnon man, who lived in Europe during the latter part of the fourth glacial period. The Neanderthal skull is that of "classic" Neanderthal man.



SKELETONS of modern man (*top*) and Neanderthal man (*bottom*) are compared.

actually this sea is not as great a barrier as it may appear. There are short crossings from Europe to Africa at both ends of the sea, and in Ice Age times apparently there were also land bridges across the mid-Mediterranean.

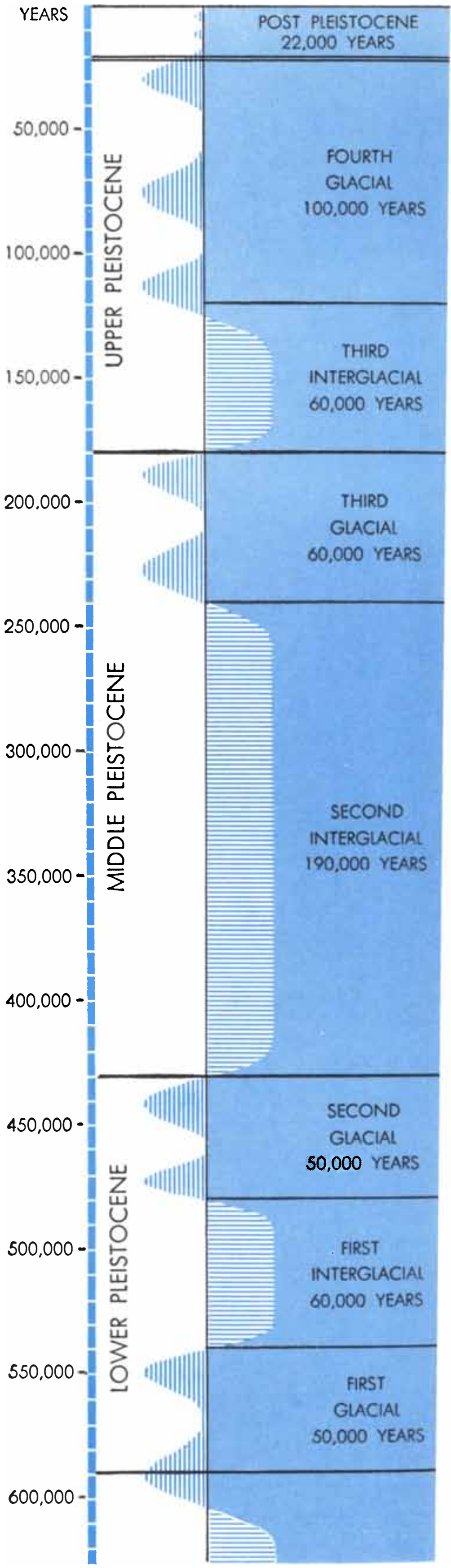
When we come to consider the climate, the geographical picture takes on more significance. During the four Ice Ages of the Pleistocene Period, Europe was largely covered by ice sheets and very cold, while North Africa and Asia Minor were warm, well watered and covered with vegetation. In the interglacial periods (between the Ice Ages), North Africa became a dry desert while Europe enjoyed a warm, lush climate [*see maps on page 92*]. So it appears altogether probable that early man, almost entirely at the mercy of nature, followed the climate—pushing north into Europe in its verdant interglacial periods and retreating to Africa when the ice sheets came. This implies that early man in the European-African world lived in the open, was not a cave-dweller and probably was late in using fire.

For the world of central and eastern Asia, on the other hand, there was no warm refuge. When Ice Ages came, southward migration was barred by the high mountains and plateaus. There was no climatic inducement to push westward over the steppes toward Europe. We can picture primitive man in this world as primarily a cave-dweller, an early user of fire and a rugged hunter of big game. And the archaeological evidence supports this surmise.

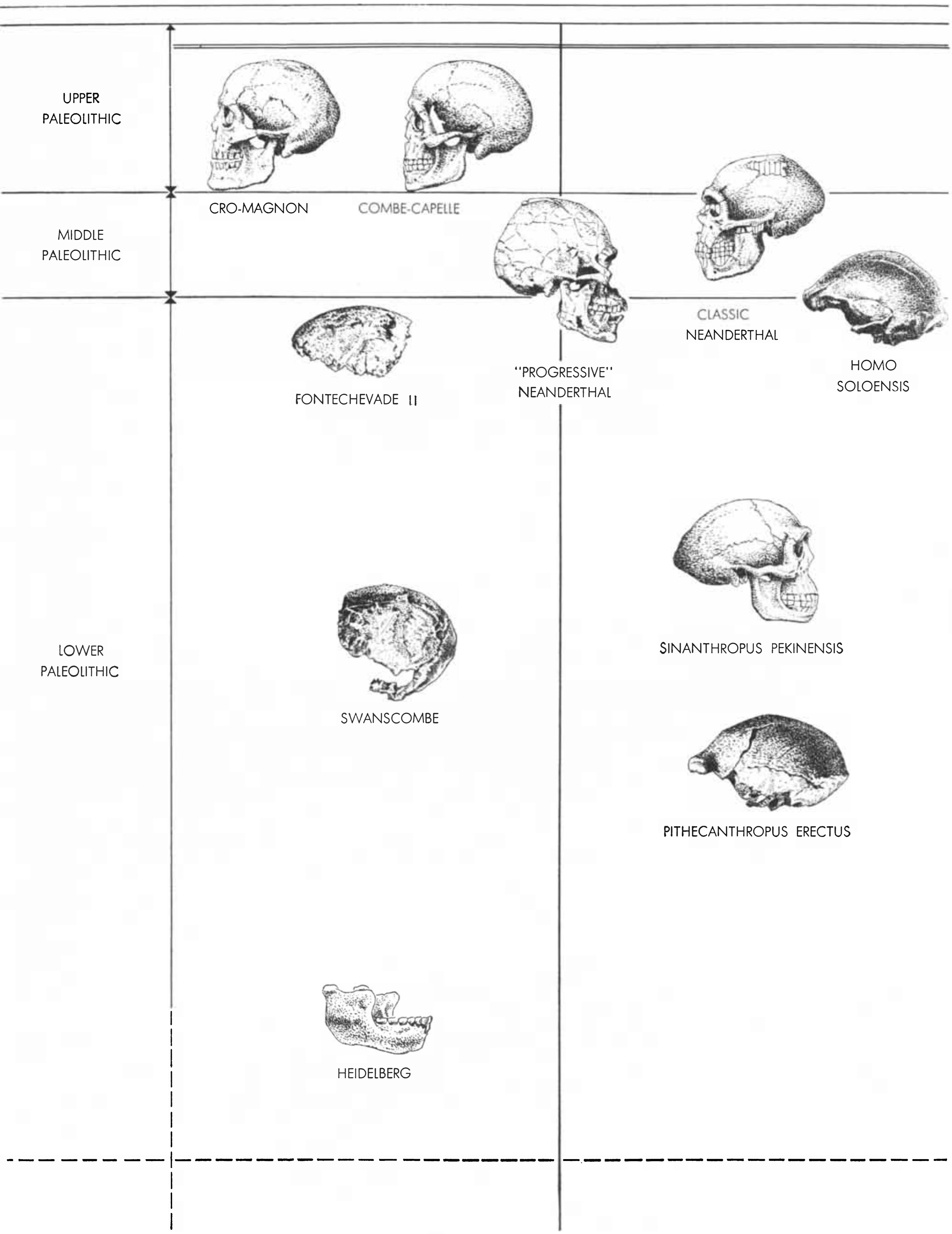
On the basis of these facts and of what we know about the earliest men, I suggest the hypothesis that Neanderthal man and *Homo sapiens* arose and developed separately in the two worlds—Neanderthal in central and eastern Asia, *sapiens* in the world of Europe, Africa, Asia Minor and India.

Let us look first at the bones. "Classic" Neanderthal man has very distinctive features: a long, low-vaulted skull, a big, jutting brow-ridge running across the forehead, a broad, low-bridged nose, a jutting, muzzle-like mouth, a retreating chin. He had a squat body with a barrel chest, bowed legs and flat feet, suggesting that he walked in a crouch with bent knees and a shuffling gait.

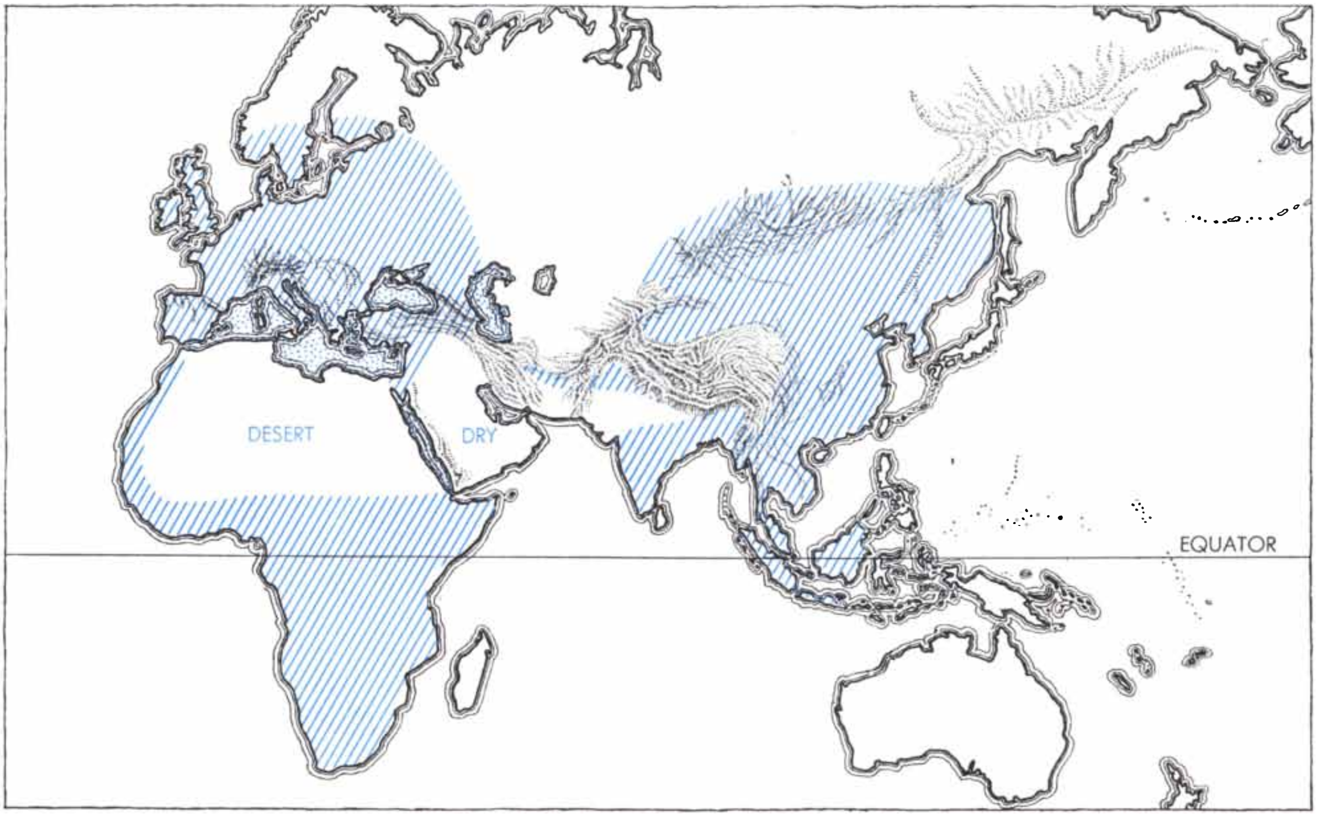
Unhappily for our thesis, no classic Neanderthal skeleton has been found in central or eastern Asia. But there has been little search for fossil man in that part of the world. The theory does find support, however, in the few fossils that have been unearthed there. All of them



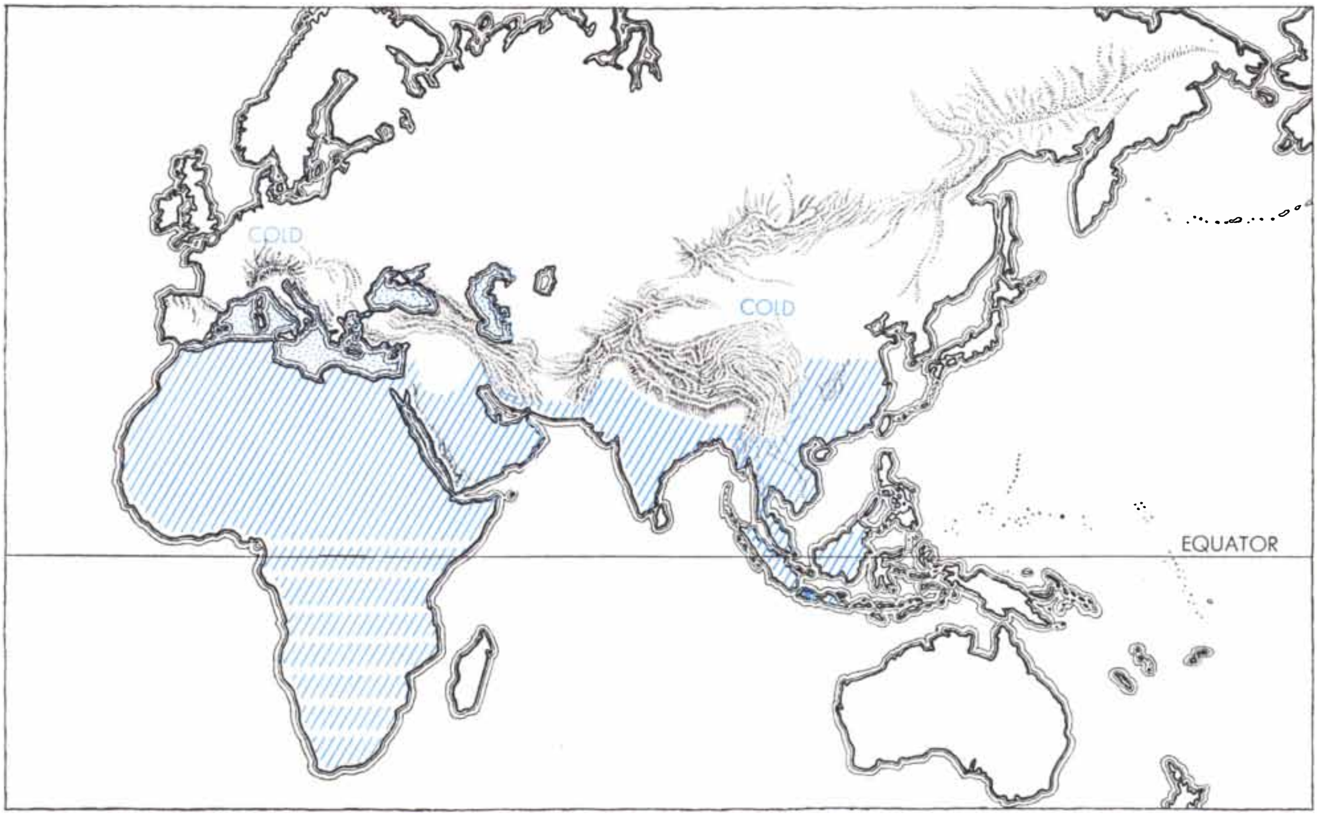
AGES OF SKULLS of *Homo sapiens* and Neanderthal man are related in this chart. The



Neanderthaloid skulls are to the right of the last vertical line to the right. The skulls of types of men related to *Homo sapiens* are to the left of that line. The hatching in the colored area at left symbolically represents the advance and retreat of the ice.



DURING INTERGLACIAL PERIODS men were separated into several isolated breeding populations by deserts, water, highlands and distance. The hatched areas indicate the environments that would have been most hospitable to men with primitive cultures.



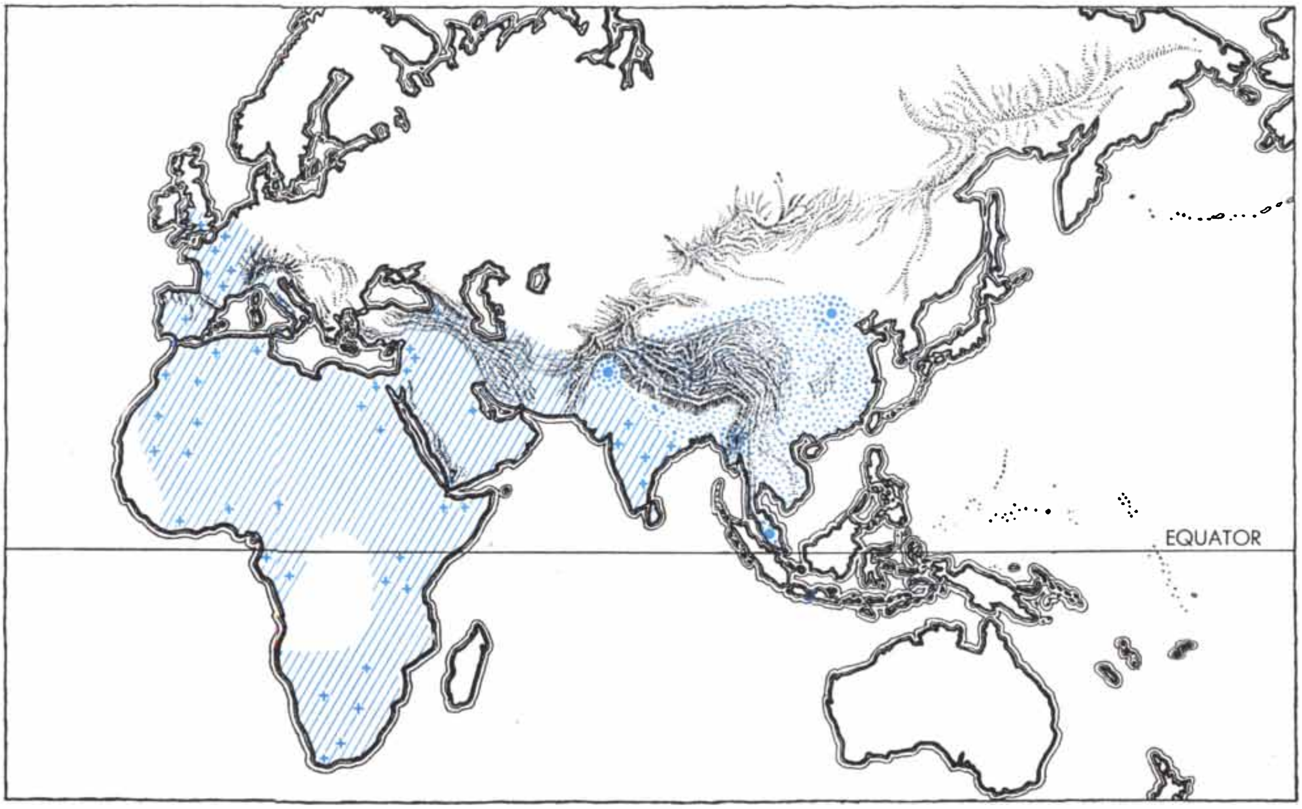
DURING GLACIAL PERIODS men were concentrated in a smaller environment. Land bridges may have enabled them to cross the Red Sea and the Mediterranean. The broken hatching in Africa indicates that this area may have been too dry for human habitation.

show strong similarities to Neanderthal. The two best known are *Pithecanthropus erectus*, found in Java, and *Sinanthropus pekinensis*, discovered near Peking. Both had low-vaulted skulls, continuous brow-ridges, low-bridged noses, muzzle-like mouths and retreating chins. Pithecanthropus and Sinanthropus resemble Neanderthal closely enough to be considered his relatives, if not his direct ancestors. They date from the middle of the Pleistocene, which makes them about 200,000 years older than Neanderthal. A third find in the Far East, *Homo soloensis* of Java, is closer to Neanderthal's time and is also more like him [*see chart on page 91*].

Now, again looking for very early human ancestors, what do we find in the world of Europe, Africa and southern Asia? Aside from the man-apes of South Africa (which probably have no direct connection with the evolution of man), the only fossils that can confidently be said to be more than 200,000 years old have been found in Europe. The oldest is the jaw of Heidelberg man, believed to date from the first interglacial period, about 500,000 years ago. Heidelberg man was once thought to be an ancestor of Neanderthal, but his teeth turn out to be more advanced than Neanderthal's and like those of *Homo sapiens*. Thus he is eligible to be considered a possible ancestor of *sapiens*. The second oldest human fossil in Europe is Swanscombe "man"—part of the skull of a young woman found in a 300,000-year-old deposit in England. Too much of the skull is missing to decide her relationship definitely, but most scholars are inclined to class her with *sapiens*. As a third, and much more conclusive, piece of evidence, there is the skull of Fontéchevade man, discovered just 10 years ago in the province of Charente in France. He seems to be fully *Homo sapiens*, and he dates from more than 150,000 years ago —before Neanderthal appeared on the European scene!

The evidence of the bones, then, seems to support the hypothesis that Neanderthal man arose in eastern Asia and *sapiens* in the western world. For hundreds of thousands of years, through the first three Ice Ages, they evolved along separate lines, until Neanderthal finally made his way to Europe some time late in the third interglacial period, less than 150,000 years ago.

A global study of the tools and ways of life of the primitive men bears out this picture of two isolated worlds. The earliest known stone tools of man



STONE TOOLS suggest that *Homo sapiens* and Neanderthal man were separated for most of their history. At first pebble tools were made in Asia, Africa and Europe. Later the hand ax was invented and became the dominant tool in the hatched area. The evolution of pebble tools continued in the stippled area. The crosses and large dots indicate regions rich in the tools characteristic of each.

were the so-called "pebble" tools—egg-shaped pebbles chipped on one side to make a crude cutting edge. They go back to the very beginning of the Pleistocene. But their development followed very different courses in the two worlds on the opposite sides of the geographical barrier. There was a sharp contrast, also, in the two ways of life.

In the eastern world men continued to get along with pebble chopper-tools until near the end of the Pleistocene. Their harsh climate spurred them, however, to progress in other directions. When the ice sheets came, the early men, trapped from moving south by the frigid Himalayan-Tibetan highlands, and probably unaware that they could skirt the mountains by traveling west, had to find ways to survive in the cold. They took up residence in caves, learned to use fire to warm themselves and to cook, and developed devices to kill big game. Even Sinanthropus, the small-brained Neanderthaloid who lived in the second interglacial some 300,000 years ago, made his home in caves and roasted the meat of large animals that he killed. In these homemaking and hunting arts he seems to have been 100,000 years or more ahead of the men in the softer world on the other side of the barrier.

In the "western" world the predecessors of *Homo sapiens* learned very early to chip both sides of the pebble and then to make stone hand-axes and flake tools. But in other ways they advanced more slowly than their precocious contemporaries in the eastern world. The archaeological evidence indicates that they lived on wild plants and small game, drifted passively with the climate to the moist and mild parts of their range, slept in the open and did not learn to use fire until the third interglacial era.

It seems that for some 400,000 years, throughout most of the Pleistocene, the two worlds had almost no contact, except in a few spots in northern India and central Asia where their culture overlapped. Then Neanderthal man suddenly invaded Europe and southwestern Asia. If the hypothesis I have presented is correct, we can begin to understand a number of archaeological finds that have puzzled anthropologists.

Let us suppose that the first proto-men, common ancestors of both Neanderthal and *sapiens*, arose from the primate animals somewhere in Africa, India or the Middle East before the Ice Ages. Some of them crossed the barrier into eastern Asia during a warm era. Then, caught by glaciations that closed the barrier, they remained in their separate world. Over several hundreds of thousands of years two divergent lines evolved—Neanderthal on one side of the barrier, *sapiens* on the other. The latter, wandering widely over Europe, southern Asia and Africa in interglacial periods, developed a variety of races but remained one species because they repooled their genes when they met in their warm Ice Age retreats in Africa, the Middle East and India.

Late in the third interglacial period Neanderthal man, driven by no one knows what circumstances, began to push westward into the Middle East and Europe. He mated with *sapiens* and produced hybrid Neanderthals of a "progressive" type—with a high-vaulted skull and some other *sapiens* features. He also developed the culture called Mousterian, associated with Neanderthal

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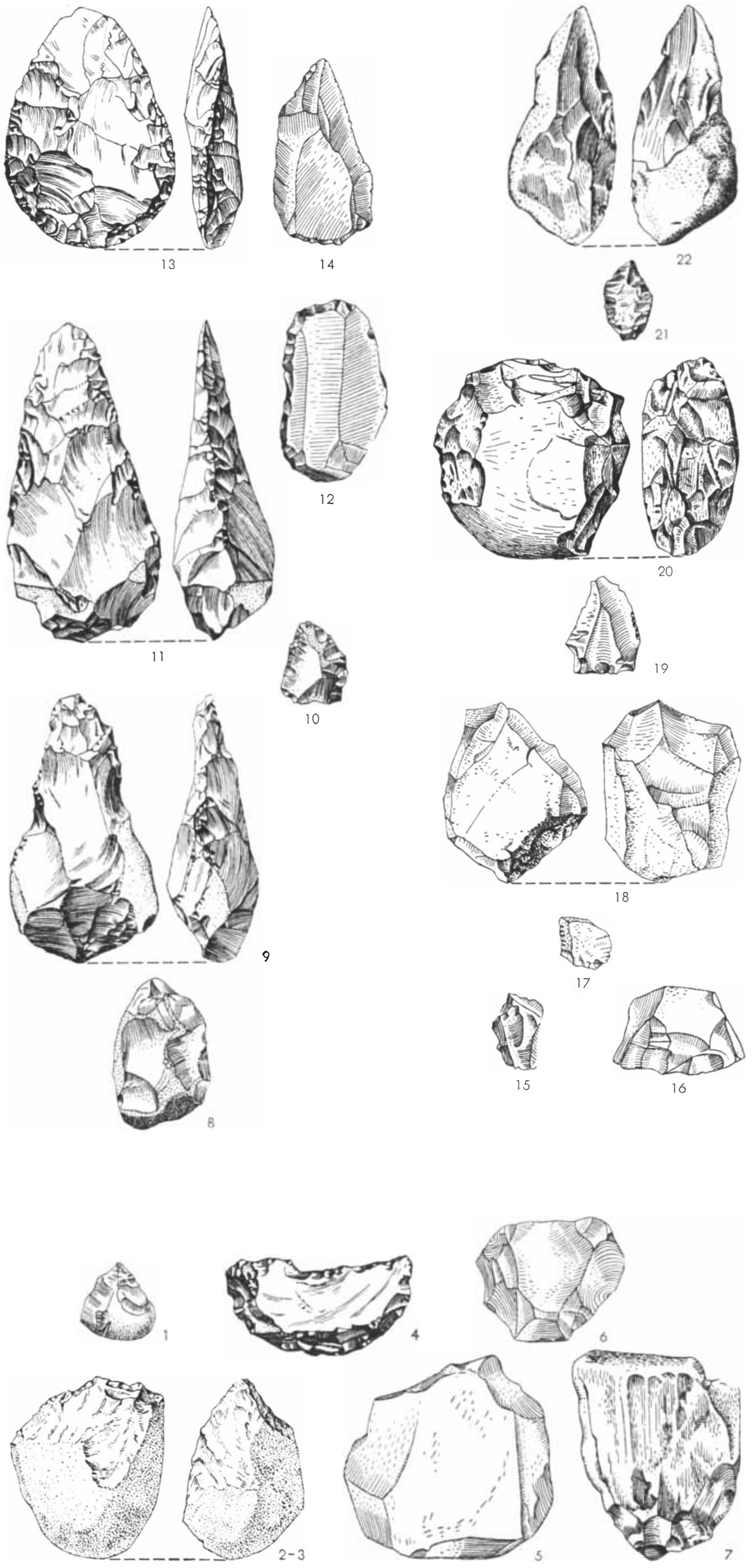

EVOLUTION OF TOOLS is outlined in this drawing. At bottom (*numbered 1 through 7*) are representative examples of early pebble and flake tools from Java, India, Africa and Europe. At upper left (*numbered 8 through 14*) are examples showing the evolution of hand axes and associated flake tools in India, Africa and Europe. At upper right (*numbered 15 through 22*) are examples showing the evolution of pebble tools during same period in eastern Asia.

man: it is a combination of cave-dwelling, fire-using and big-game-hunting with the stone-chipping techniques of the west.

When the Fourth Ice Age came, *Homo sapiens* retreated south. Neanderthal men, still pushing in from Asia, took over Europe. These "classic" Neanderthals blotted out the progressive physical traits acquired by the earlier Neanderthal migrants who had mated with *sapiens*. Thus my hypothesis would explain a paradox which has long troubled scholars: namely, that the latest Neanderthals found in Europe are all of the "classic" or conservative type, although they lived later than "progressive" Neanderthals found in Palestine and elsewhere. It would also explain the late classic Neanderthals found in Iraq [see "Shanidar Cave," by Ralph S. Solecki; SCIENTIFIC AMERICAN, November].

During a relatively warm spell in the Fourth Ice Age some 80,000 years ago, Neanderthal man suddenly disappeared—no one knows why. *Homo sapiens*, now in the form of Cro-Magnon man and other near-modern types, returned to Europe. He also spread rapidly to eastern Asia and to the Americas. For the first time *sapiens* showed an aggressiveness of spirit and a burst of cultural advance which had been foreign to his nature in the preceding hundreds of thousands of years. For this he may well have had Neanderthal to thank in large part. *Sapiens* began to live regularly in caves, to bury his dead with grave offerings, to hunt big game, to use fire, to make specialized tools, to clothe himself and to produce religious art. Probably all or most of these new accomplishments were heritages from Neanderthal man.

So we may owe to our extinct distant cousin, Neanderthal man, the impetus that freed mankind from a grubbing, parasitic existence and made him independent of climate and the master of his environment.

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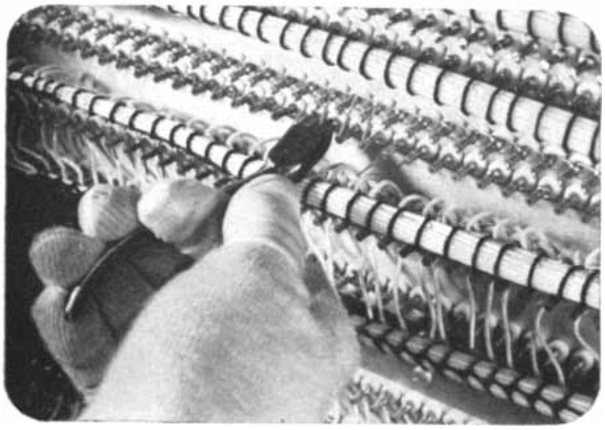

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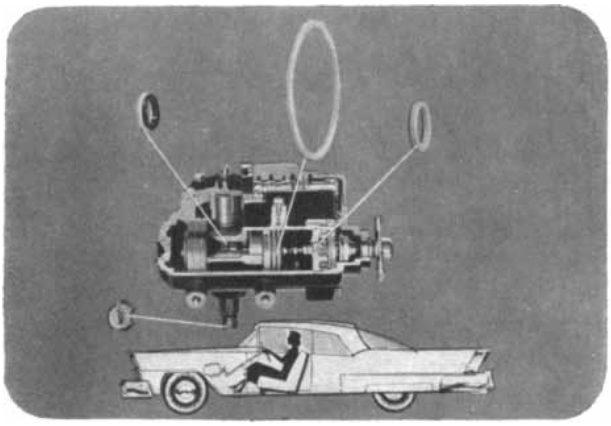

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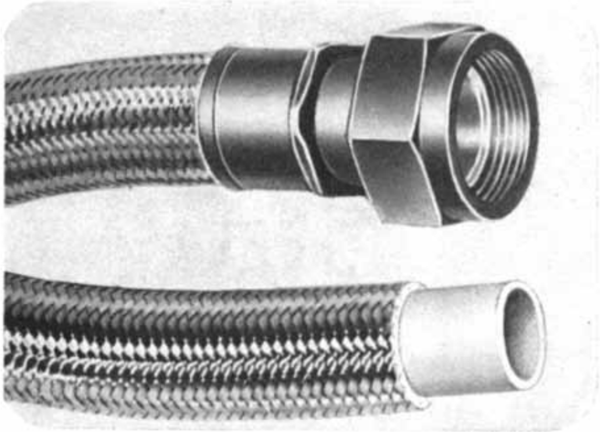

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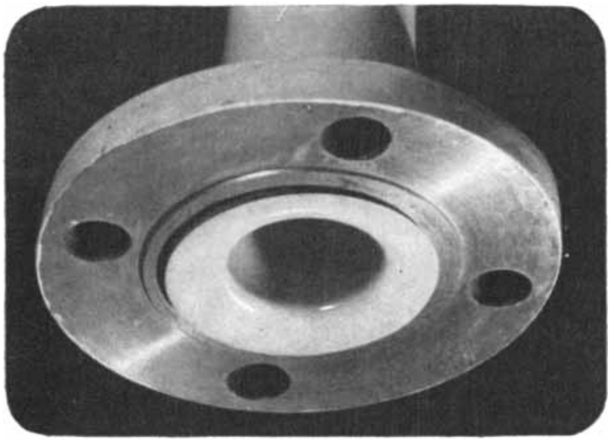

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Heinrich Hertz

The last great physicist of the era before the discovery of X-rays, radioactivity and subatomic particles, he is best remembered for his demonstration of the connection between electromagnetism and light

by Philip and Emily Morrison

We celebrate this year the hundredth anniversary of the birth of Heinrich Rudolf Hertz, born February 22, 1857, in Hamburg. In his tragically short life of 37 years this brilliant, gentle man brought the era of "classical" physics to a glorious culmination. It was his insight into the meaning of the Maxwell theory of electricity and magnetism, leading to his discovery of radio waves, that opened up the great spectrum of waves other than light, which has been explored so rewardingly by physics and exploited in a thousand ways by modern technology. Hertz mounted to the great divide in physics, but of the new world on the other side he got only a Pisgah view—a mere glimpse of the Promised Land. He was the first to observe the phenomenon of the photoelectric effect, but he could not recognize what it meant. Hertz died on the very eve of the birth of modern physics. The discoveries of X-rays, radioactivity and the electron came within three years after his death.

HERTZ was born in 1857 and died only 37 years later. He was a student of Hermann von Helmholtz at the University of Berlin, and himself worked at Kiel, Karlsruhe and Bonn.

The intellectual climate in which young Hertz was born has been portrayed for us, in all its expansive vigor, by Thomas Mann's novels. Like Hanno Buddenbrook, the last of that close-knit family, Hertz was the son of a senator of a great Hanseatic city. He went to *Realschule* in Hamburg, and we can imagine him, like Hanno in Lübeck 40 miles away, struggling with Ovid and oppressed by the fetid air of the chemistry hall. Hertz, however, was a bright student: he became fluent in Greek and even tried Arabic. Fond of working at bench and lathe and of building instruments, living in the blossoming time of the machine industry, young Hertz felt impelled to a career as an engineer, but as his schooling advanced he came to the sure conclusion that he could be happy only in science. He wrote of his decision to his parents: "All else seemed hollow and unsatisfying." The young man went to study at the University of Munich and in the fall of 1878 enrolled in the University of Berlin, then perhaps the center of science on the Continent. There he became a student of the great Hermann von Helmholtz.

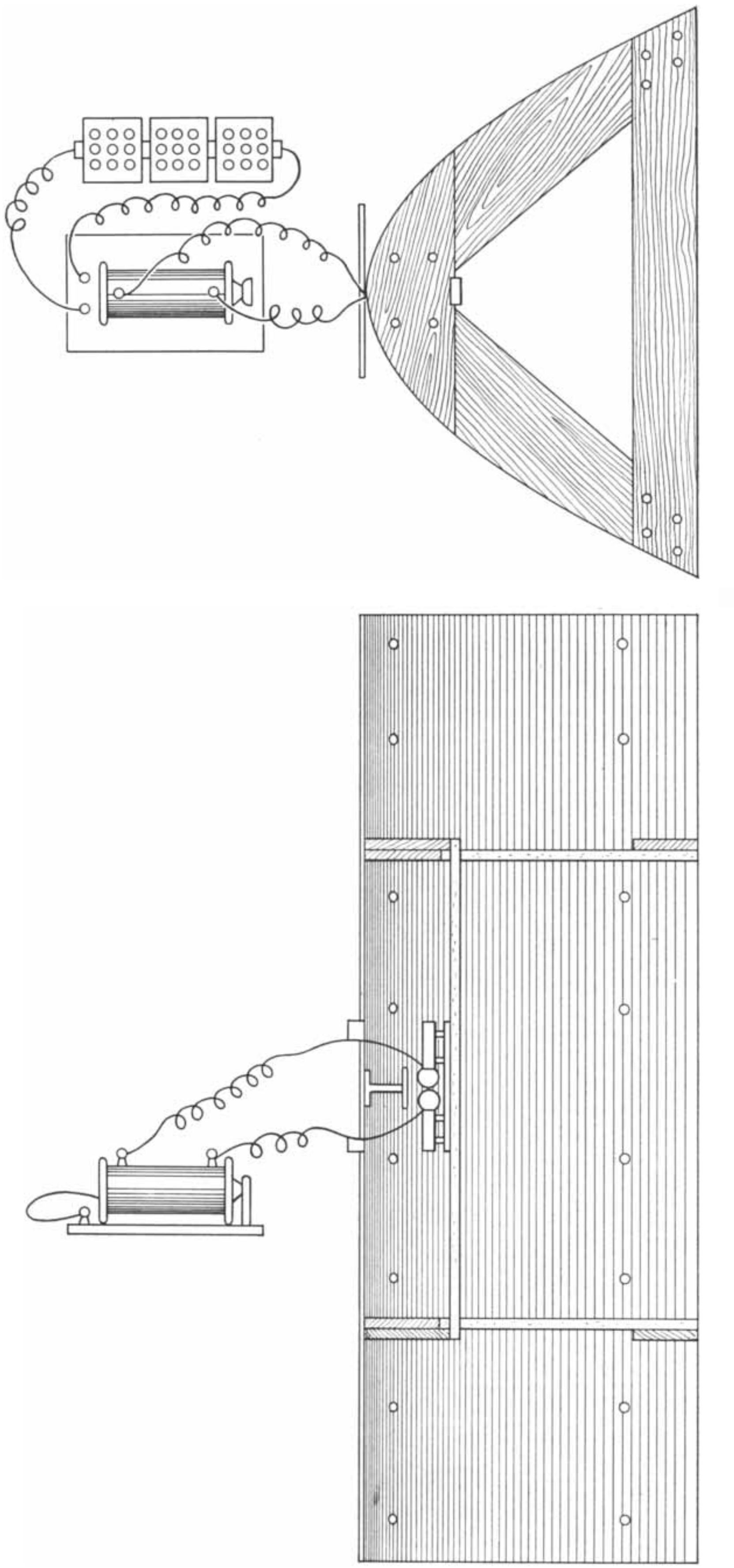
He won the master's attention at once. Helmholtz wrote: "I saw here that I had to deal with a pupil of quite unusual talent; and when . . . it fell to me to propound to the students a subject of physical research for a prize, I chose one in electromagnetics in the belief that Hertz would feel an interest in it, and would attack it, as he did, with success." Hertz's paper, entitled "Experiments to Determine an Upper Limit to the Kinetic

Energy of an Electric Current," was awarded the prize, with high commendation. (He wrote to his family that he chose to receive the gold medal instead of a cash prize and was disappointed to find that it bore no inscription to indicate that it came from the University.) Hertz received his doctoral degree *magna cum laude*, a rare distinction at Berlin in those days, and Helmholtz then made him his assistant and demonstrator.

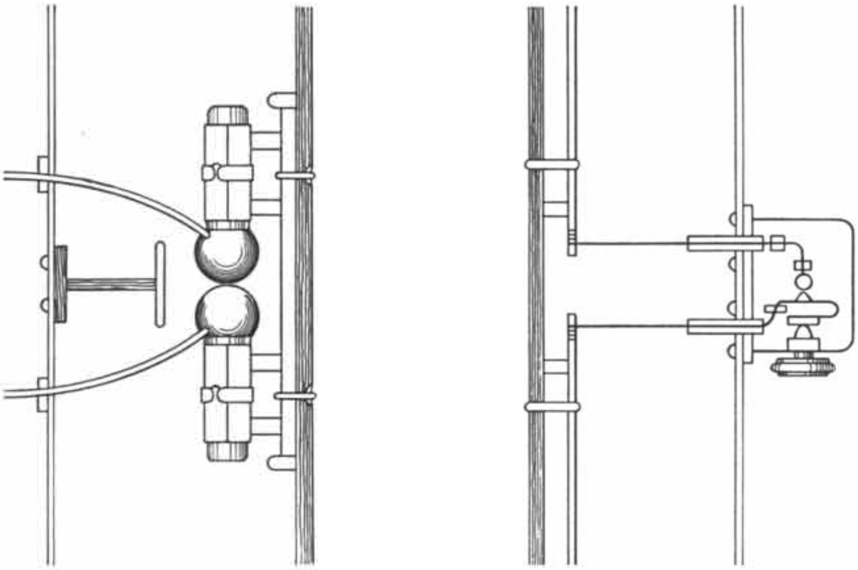
Hertz became immersed in research on many problems, experimental and theoretical. His first few papers dealt with the behavior of oscillating electric currents. Then he carried out a couple of elegant studies on hardness as a mechanical property and on the elasticity of solids; the latter paper is still a major achievement in this refractory branch of physics. Curiosity about the collisions between ice blocks on the river in deep winter led him to a theoretical study in mechanics; investigations of evaporation drew him into work on vacuums and the cathode discharge.

Hertz kept his parents informed about his work and experiments. On devising a new hygrometer, he wrote his family a lengthy letter concluding: "I may here give a little calculation which will show father how the air in the morning-room should be kept moist. . . . This has become quite a long lecture, and the postage of the letter will ruin me; but what wouldn't a man do to keep his dear parents and brothers and sister from complete desiccation?" He described to his family in detail how he built a storage battery of 1,000 small cells, "working away just like a mechanic," and how he blew glass tubes for gas-discharge experiments to save time and expense: "My impatience will not allow me to order from the glass blower today a tube which would not be ready until several days later, so I prefer to restrict myself to what can be achieved by my own slight skill at the art."

In 1883 Hertz left Helmholtz's laboratory to step up to the traditional first rung of the academic ladder in German universities: he was appointed *Privatdocent* at the minor University of Kiel. Kiel was not very well equipped, and Hertz did his best to continue his work by setting up a laboratory in his own home. Two years later, at 28, he was called to the Technische Hochschule at Karlsruhe as professor of physics. There, in the green month of April, he met Elizabeth Doll, a professor's daughter, and after a whirlwind courtship they were married in July. In beautiful Karls-



HERTZ'S APPARATUS to generate and focus electromagnetic waves is shown from above (*top*) and from the side (*bottom*). It produced waves about two feet from crest to crest.



HERTZIAN WAVES were transmitted by a rod interrupted with a spark gap between two large knobs (*left*). The waves were received by another interrupted rod (*right*). The spark gap of the second rod was between the small sphere and point which appear at the far right.

ruhe, with his personal life so happily arranged, and with experimental facilities almost of the first class, Hertz began the series of electrical investigations which were to make his name immortal.

It is worthwhile to look at the physics of the time with Hertz's eyes. Mystery surrounded the transmission of electricity and magnetism. To be sure, the genius of James Clerk Maxwell had formulated a complete electromagnetic theory, summed up in compact and elegant differential equations. But the theory was difficult for the time. It was a bit like P. A. M. Dirac's theory of the spinning electron in 1932 or thereabouts—beautiful, obscure, apparently powerful but uncomfortably far at the time from any clear way to test it experimentally. Hertz wrote of Maxwell's theory: "On account of the difficulty of the theory the number of its disciples at first was necessarily small. But everyone who studied it thoroughly became an adherent, and forthwith sought diligently to test its original assumptions and its ultimate conclusions."

Its greatest adherent was young Hertz, and he set out to examine its assumptions and "ultimate conclusions" in a concrete way. The problem was to prove the existence of a relation between light and electricity. As Hertz told his lecture audiences in his wonderful popular exposition of Maxwell's theory: "I am here to support the assertion that light of every kind is itself an electrical phenomenon—the light of the sun, the light of a candle, the light of a glowworm." In our day of the ubiquitous television aerial and the radar dish, it is hard to place ourselves back in that time—when light waves seemed to have not the remotest connection with the Leyden jars and the other paraphernalia of the electrical laboratory. But on the well-laid foundations of Maxwell's equations Hertz proceeded to build a bridge between them.

His design for testing the theory was simply to generate waves by electrical means and to show that these waves would travel through the "ether" in the same way and with the same speed as light. Generation of such waves should be no great problem. It was well known that the electrical discharge from a Leyden jar was not a one-way current but a rapid oscillation. In fact, the German physicist Berend Wilhelm Feddersen had actually seen the oscillations, by viewing a spark discharge with a fast-rotating mirror which showed that the sparks jumped back and forth across the gap, clearly reversing direction a hundred thousand times per second. Hertz reasoned that such oscillations, if propagated through the "ether," ought to be detectable by a resonant receiver some distance away from the transmitting source. A receiver of the appropriate length would pick up the oscillations, and they would induce in it a current which would be signaled by the appearance of a spark across its gap.

As his receiving "antenna" Hertz used a wire or brass rod a foot or so long, which meant that the waves he worked with had to be of very high frequency. He could estimate that the appropriate frequency was in the hundreds of mil-

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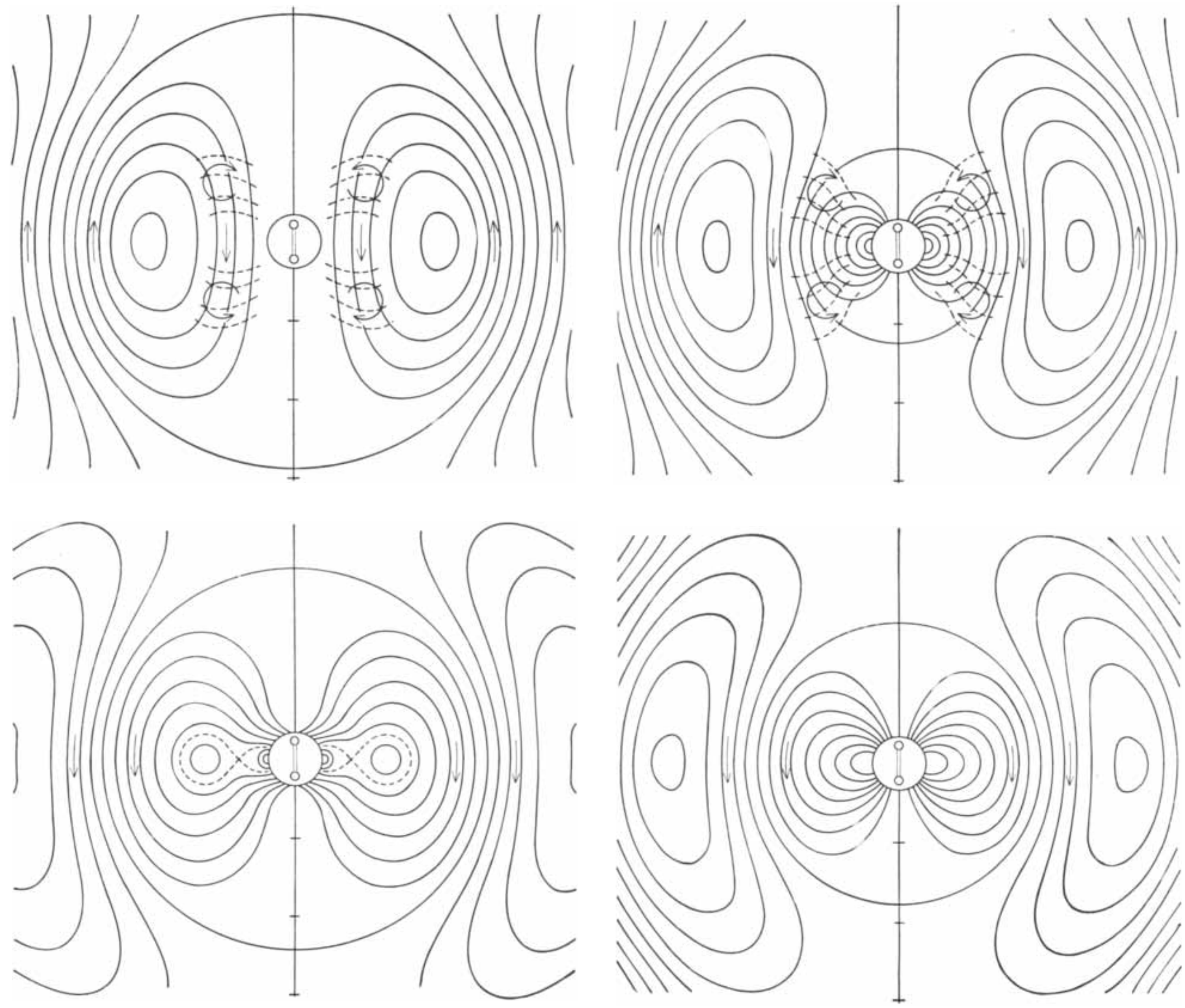
Where Reliability for Your Product Is Our Constant Goal lions of cycles per second—that is, in what we call today the microwave region. Hertz devised a simple contraption to generate these waves. In the fully developed version of his experiments he used an induction coil very like the spark coil of a Model T automobile engine to convert battery current into high-voltage pulses; these were fed by wires to a one-foot brass rod broken midway along its length by a small gap, with knobs as the poles [*see diagrams on page 100*]. The sparks produced across the gap generated current oscillations in the rod with a wavelength of about two feet (roughly double the length of the rod), which corresponds to a frequency of 500 or 600 megacycles. Some distance away from this transmitter he placed his receiver—a similar broken straight rod, with a tiny spark gap having as its two poles a little knob and a sharp point. The size of the gap was adjustable with micrometer fineness.

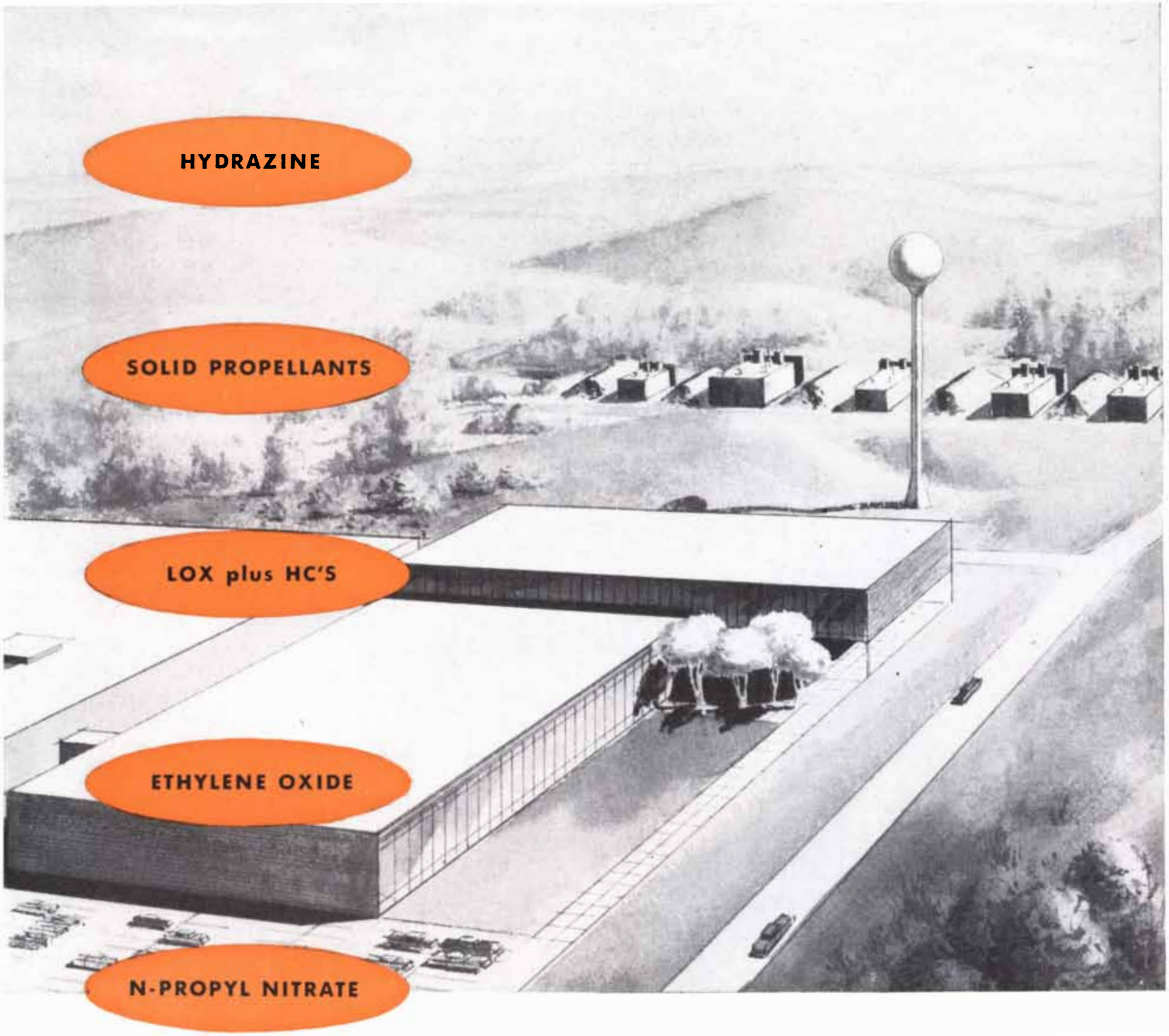
Hertz's first historic experiment took place in the physics lecture hall at Karlsruhe. He set up his transmitter at one end of the hall, his receiver at the other end, and in the darkened hall he glued his attention to the receiver's spark gap. And lo! tiny sparks flashed there the instant the distant transmitter was turned on. The sparks were only a few thousandths of an inch long and lasted no more than a microsecond, but the human eye is a most sensitive receiver. Hertz wrote: "In a perfectly dark room [the sparks] are visible to an eye which has been well rested in the dark."

Here, then, were electromagnetic waves other than light, traveling through the "ether" as light did. How to prove that the new waves were like light waves? Time was the essence: did these waves move with light's speed? In Hertz's laboratory, measurement of their velocity was impossible. To measure the time of travel from the transmitter to the receiver required exquisite timing with extremely sharp pulses. As Hertz remarked: "If we wish to measure a length correct to the tenth part of a millimeter, it would be absurd to indicate the beginning of it with a broad chalk line." Hertz had no oscilloscopes, no electronic tubes of any kind—in short, no means of measuring the velocity of his waves directly. Instead, he measured their wavelengths, and in this way confirmed Maxwell's calculations. Hertz made these measurements by studying the interference between direct waves and returning waves reflected from a zinc-covered wall acting as a mirror.

More convincing were his experi-



ELECTRIC FIELD around Hertz's oscillator is mapped. The second, third and fourth drawings each show the lines of force one eighth of a full period of oscillation after the preceding drawing. All the drawings in this article closely follow Hertz's originals.



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ments showing that his electrical waves behaved like light waves in various contexts. He focused his waves with big mirrors of galvanized sheet; he refracted them with large prisms made of coal-tar pitch; he found that a tinfoil screen, or the body of his assistant, cast a "shadow" when placed in the path of the electrical rays. But oddly, only conducting materials cast such a shadow; insulators did not stop the ray. Hertz wrote: "It passes right through a wooden partition or door, and it is not without astonishment that one sees the sparks appear inside a closed room."

So now one had waves imperceptible to the eye, waves which found thick doors not opaque but lucid, waves scaled up hundreds of thousands of times from the wavelengths of visible light, yet waves which nonetheless obeyed laws of physical optics. All was as Maxwell had represented it: sunlight, candlelight, glowworm light and electric current were of a kind.

The importance of Hertz's work was recognized immediately. Honors poured in upon him from all over Europe. He was called in 1889, three years after his discovery, to the University of Bonn's chair of physics, made eminent by the great Rudolf Clausius, who had just vacated it by his death. Physicists began to look into the new regions of the electromagnetic spectrum which Hertz had widened so dramatically, and some of them soon foresaw practical uses for the Hertzian waves. In 1892 Sir William Crookes wrote of the possibility of communication with Hertzian waves, and Guglielmo Marconi, inspired by reading Hertz's own account of the waves, sent his first wireless messages in 1895, only nine years after Hertz's laboratory discovery. But Hertz himself, strangely enough, showed no prescience about possible uses of his waves; he even argued that they could not be of any practical use.

Hertz now entered upon experiments which fell just short of crossing into the new world of physics—the world of the electron and the atom. He had already, in fact, observed some atomic phenomena without recognizing what they meant. He had found that ultraviolet light from the transmitter's spark could touch off sparks in the receiver, but he did not realize that this was a photoelectric effect: that is, that the light initiated current in the receiver by releasing electrons from the surface of its negative pole. The electron had not yet been discovered. Hertz had come close to discovering electrons in his

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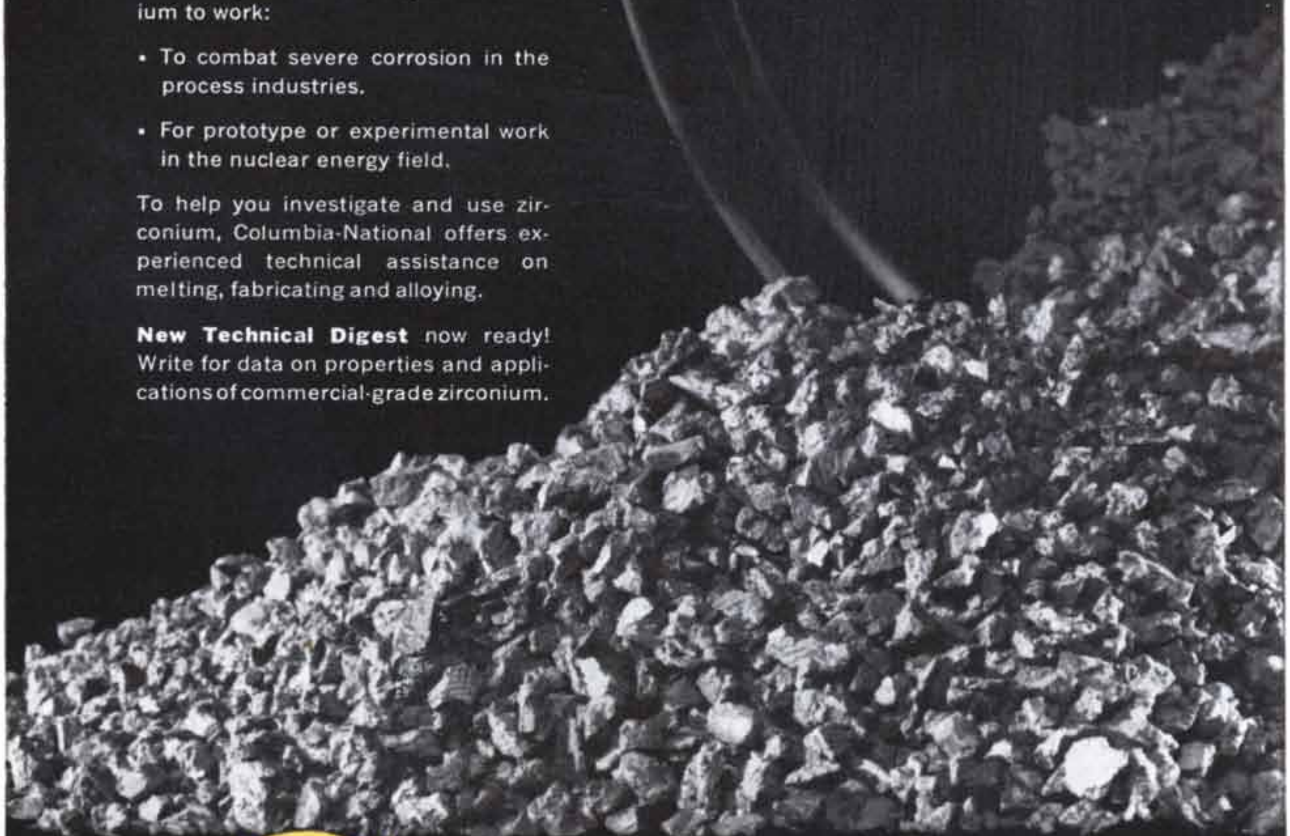

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earlier experiments with cathode rays at Berlin. Seeking to determine whether the cathode rays were electromagnetic waves or a beam of particles, he had subjected cathode rays in a vacuum to a strong electric field. If the rays were made up of charged particles, the field should deflect the beam; if they were waves, they would ignore the field. Hertz found the rays completely unaffected by the field. Unhappily his vacuum was inadequate; it contained enough residual gas to shield the rays from his electric field. J. J. Thomson, with a higher vacuum, was later to discover the electron by producing exactly the effect Hertz had sought.

At Bonn, Hertz took up again his experiments with cathode rays. He showed that the rays could pass through thin foils of metal. Had he proceeded further, he might have discovered that the emerging rays were X-rays. But this was his last experiment. Hertz, so gifted, so happy, still a young man in his prime, was cut down by cancer. An unsuccessful operation on malignant bone in 1892 left him ill and depressed; his diary bears the phrase "an unhappy time, fatigue, disgust." He gave up the laboratory and turned to theoretical work on mechanics, producing a reformulation of theory which was published after his death under the title *Principles of Mechanics*. The book bore an introduction by Helmholtz—a touching tribute by the still-living 73-year-old master to the young friend who had died at 37. Hertz's strange, cold, brilliant book on mechanics has had little influence, although it is in many ways profound and novel. But philosophers of science have lately rediscovered it, and the book has now been reprinted in English translation—the only work of Hertz available today in English.

Hertz, in pain and failing health, went on lecturing until December, 1893. He died on New Year's Day of 1894. His widow lived until 1942, and his two daughters, one a biochemist, the other a physician, are still living in Cambridge, England, where they came with their mother in 1937 when life in Nazi Germany grew intolerable for the family of a Hertz.

Heinrich Rudolf Hertz will be remembered as the last of the great classical physicists; but for the illness that allowed him only half a lifetime, he might also have been a great name in atomic physics. It is heartening to recall this gifted and engaging man—ingenious and energetic in experiment, profound in theory, philosophical in bent, amiable in every way.

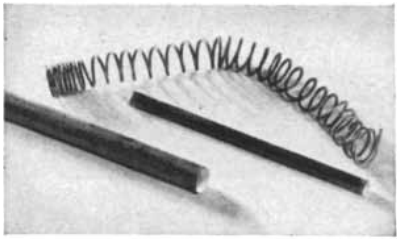
RARE EARTH RESEARCH

Recent interesting rare earth research developments

a report by LINDSAY

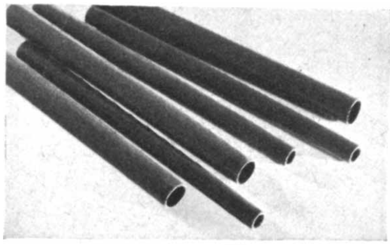
We are frequently fascinated by the imagination of researchers who are working with the rare earths. It appears that technical people, observing the many essential uses of rare earth salts in chemical and industrial processes, are looking at these fifteen unique elements as a fertile field for exploration.

During recent years, rare earths have been accepted as basic chemical tools in a wide cross section of American industry. This suggests that fruitful results may be expected from the rare earth research projects currently being carried on in industrial laboratories and pilot plant operations from coast to coast. Here, for instance, are half a dozen which may interest you.



MILES OF MISCH. This isn't a new application, but we're wondering if you know that misch metal (an alloy of the mixed rare earths) is available in wire form as well as in ingot and rod form? Cerium alloys can also be had in powder form; they are used as getters in vacuum tubes. We don't make the metal, but we can put you in touch with those who do.

FLAME SPRAYING. A new process for flame spraying various refractory oxides on metallic surfaces has been brought to near completion. Titania, zirconia and alumina can be flame sprayed, but the thing that interests us is that flame sprayed cerium oxide has some unusual properties. Rare earth oxide is a good heat radiation material, and it seems that metallic surfaces coated with rare earth oxide radiate heat much faster than do untreated surfaces.

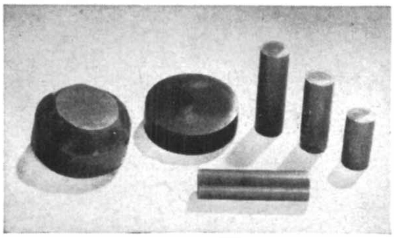


RARE EARTHS IN PLASTICS. We frankly don't know what sort of things rare earth-impregnated plastics could be used for, but a couple of people have taken enough interest in this problem to make up experimental samples. We've been doing some playing with them ourselves and have some ideas about using them. Polyethylene, for example, can be fabricated to hold up to 5 to 10 times its weight of rare earth oxide, and we've even seen some precision-bore epoxy tubing made with a rare earth oxide filler.

SEPARATION AND SAMARIUM. We are like a slaughter house in that we would like to use everything that a rare earth separation process turns out, including the squeal. With the interest that has been generated in using gadolinium as a neutron absorber (thermal cross section about 46,000 barns), we have accumulated quite a pile of samarium oxide in rather decent purity. In the process of separating gadolinium and some of the other rare earths, samarium is produced as a by-product. If you can think of a use for samarium, we have the samarium compounds.

RARE EARTH GARNETS. These are structurally somewhat similar to the garnet variety grossularite (formula $Ca_3Al_2(SiO_4)_3$). The most interesting ones are the rare earth-iron garnets such as $Y_3Fe_2(FeO_4)_3$. This mouthful of formula has been abbreviated by researchers to "YIG" for obvious reasons. Other names stem from other rare-earth symbols. These garnets, particularly those of yttrium, gadolinium, erbium, and some others have interesting ferromagnetic properties, making them useful as ferrite materials in electronic equipment. We don't make the garnets, but we do make the rare earth oxides needed to prepare them.

SINTERED SHAPES. One of our friends once wanted to know if rare earth oxides could be pressed and sintered into shaped pieces. Apparently they can, and our friend made up some experimental hot-pressed rare earth oxide and cerium oxide pieces for us.



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TOOTH DECAY

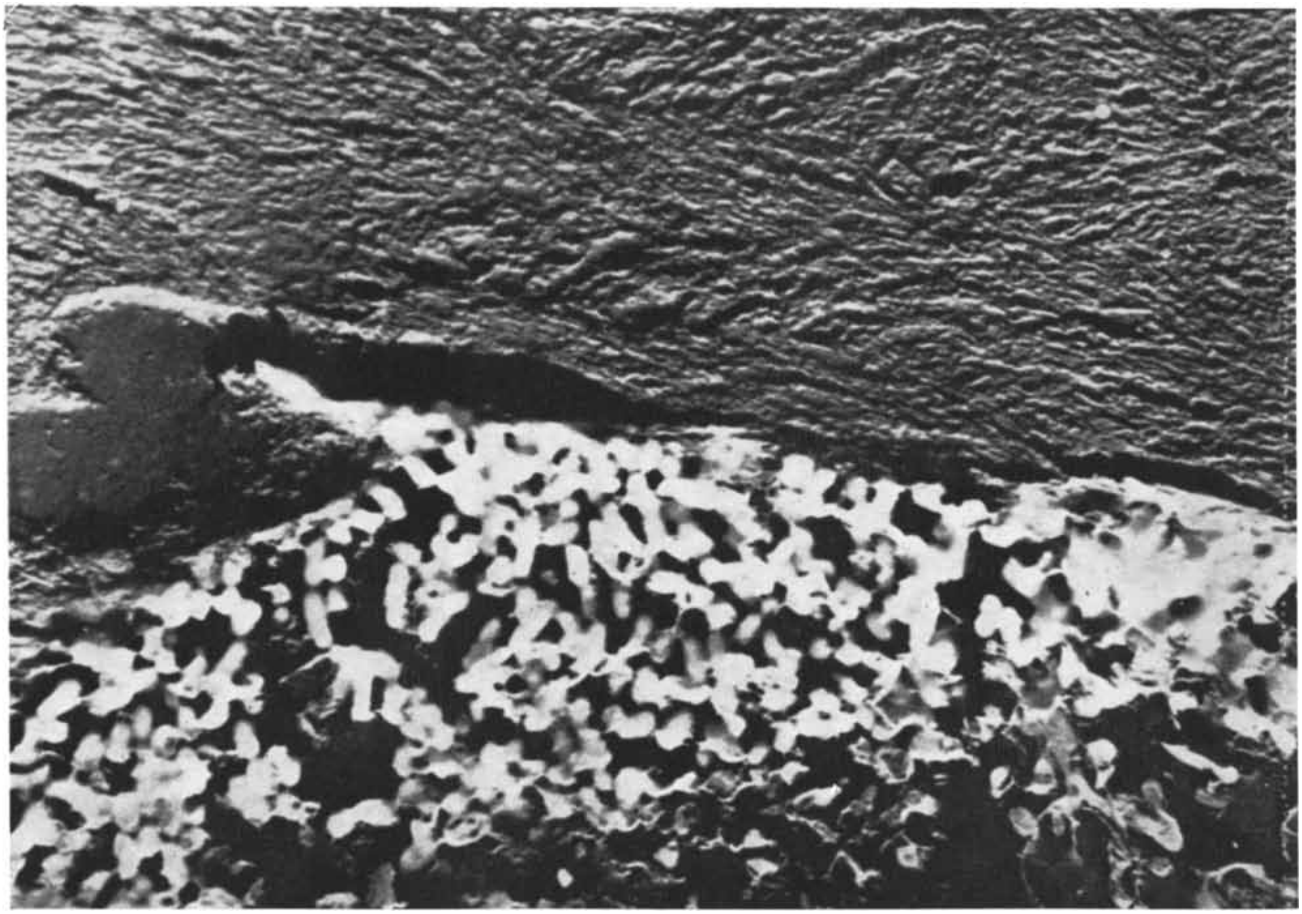
The status of the problem: Tooth enamel is not a rocklike substance but a living tissue. It is sometimes invaded by bacteria, depending on heredity, nutrition and other factors influencing the individual

by Reidar F. Sognnaes

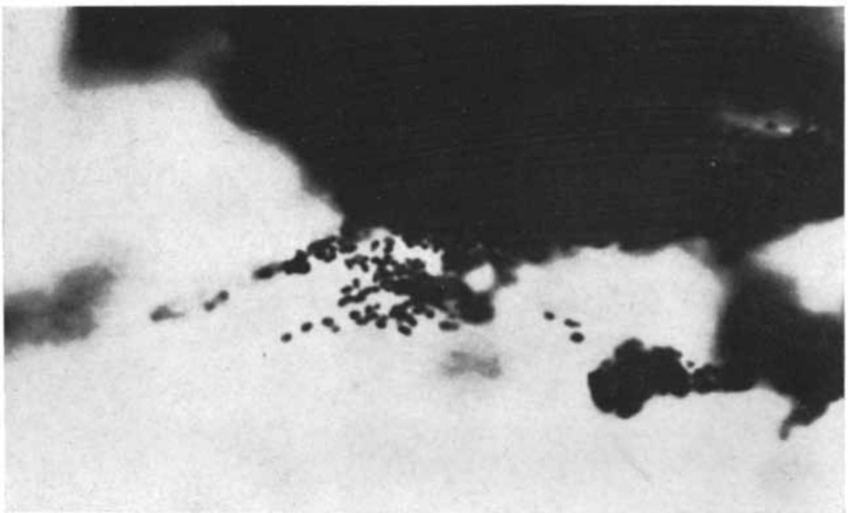
For the tooth misery that brings us all at unpredictable intervals to the dentist's chair and now costs the U. S. people more than $1,600 million per year, we can lay part of the blame on the fact that dental skill has become almost too effective. We expect the dentist to repair all defects, even to improve on nature, and therefore we accept the familiar cavity as a not too serious condition of modern life. As a result we know all too little about what causes our nation's most common and most costly disease. Why spend effort on research into the causes when we already have the cure?

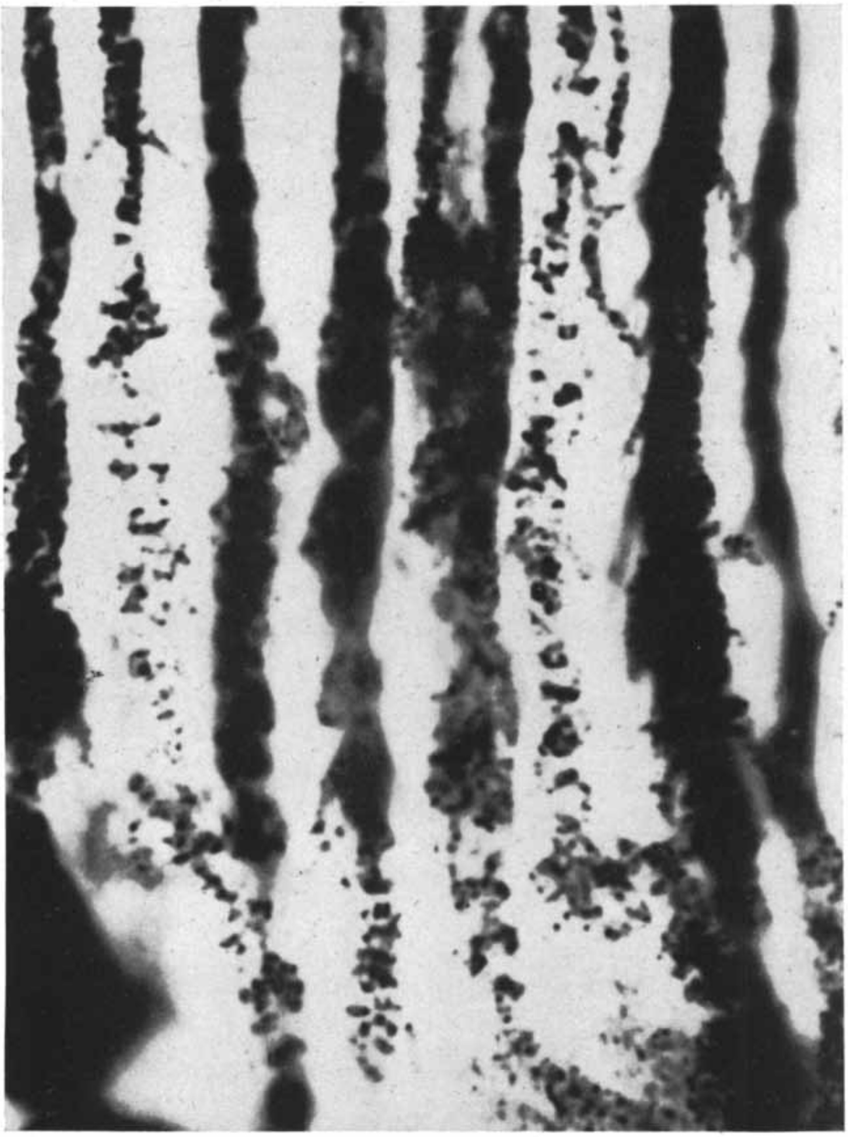
One answer is that the dentist is taking care of only one third of our population's dental ills. There is an estimated backlog of 700 million unfilled cavities. By the age of 35, more than two thirds of the American people are in need of bridges or dentures to replace lost teeth. To keep pace with all our dental needs would require three times as many dentists as we have, and the cost would be tremendous. Prevention is the only rational solution; research the only hopeful approach.

Fortunately dental research has now



ENAMEL OF A HUMAN TOOTH partly covered with bacteria (*bottom*) is enlarged 10,000 diameters in this electron micrograph made by David B. Scott of National Institute of Dental Research and John T. Albright of the Harvard School of Dental Medicine.



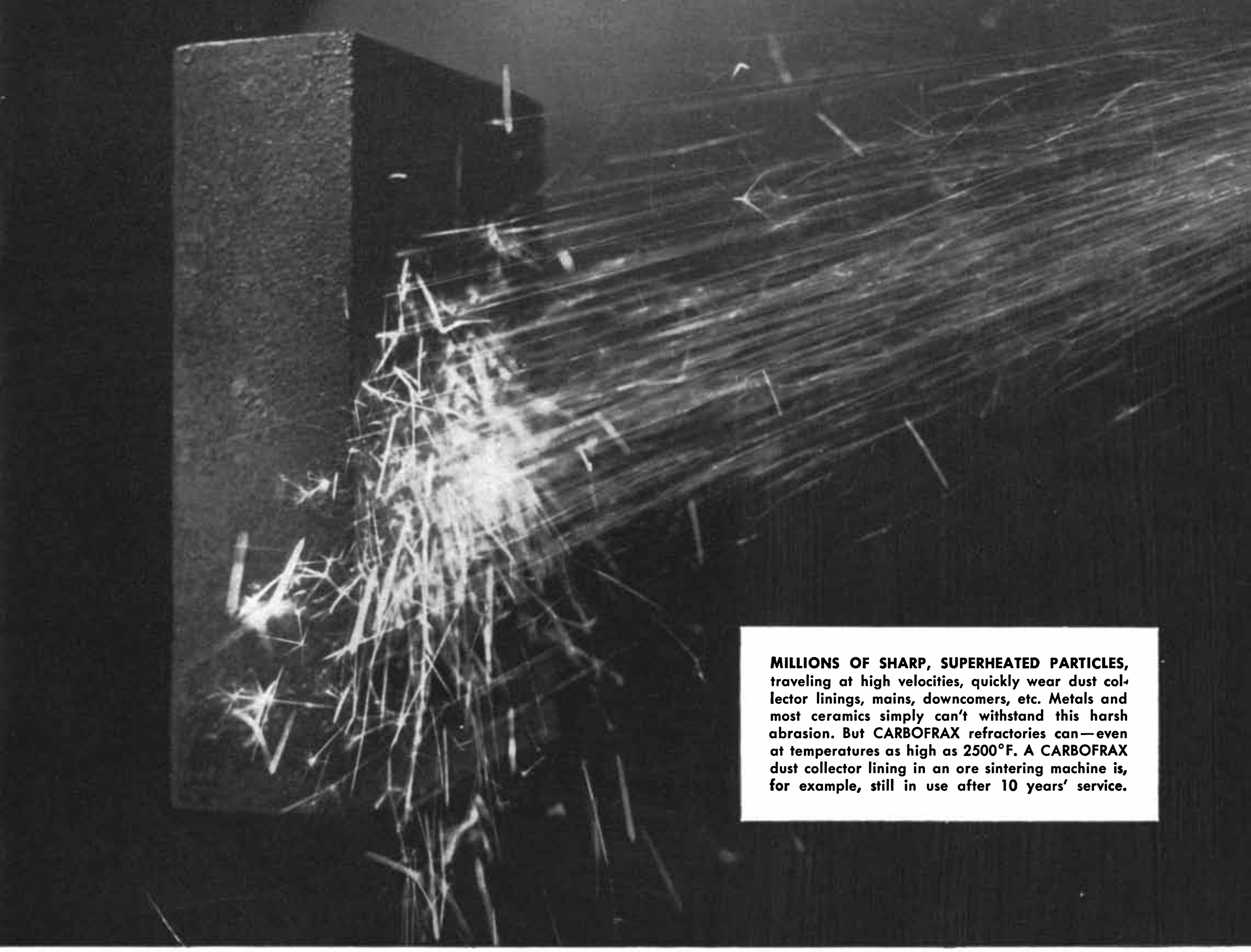


DECAYING MOLAR TOOTH **of a rat is shown in section by these photomicrographs. At top bacteria (*dark spots*) penetrate the transparent enamel layer. At bottom the bacteria invade the slender canals in the dentin which lies beneath the enamel of the tooth. These canals normally contain protoplasmic extensions from dentin-forming cells in the pulp of the tooth. The bacteria destroy the protoplasm as well as the adjacent tendon-like substance.**

begun to attract scientific interest and financial support. The first fruits of this study have confirmed some of our common notions about the cause of cavities. Clearly implicated is grandmother, sweetly dispensing "sugar and spice and all that's nice." Recent research has led the trail back further into the life history of our teeth, and grandmother is again in the picture. For now it appears that her biological contribution to what little boys and girls are made of—the genetic background, in other words—has a significant role in our dental troubles. Along with our heredity and last night's snack we are now able to implicate certain other decisive factors which act on the teeth from the cradle to the grave. Our new understanding has taken much of the dogmatism out of the old arguments about the causes of tooth decay. It shows that the process is a great deal more complex than was supposed. Although its true nature remains obscure, we know for sure what dental decay is not. It is not an allergy, an inflammation, an atrophy or a cancer; it is a disease in a class by itself.

The slogan "a clean tooth never decays" arose from a theory which dates back to the days of Louis Pasteur and had its widest acceptance in the 1890s with the publication of W. D. Miller's classic *Micro-Organisms of the Mouth*. Tooth decay was pictured as a kind of chemicoparasitic process. The microorganisms fermented carbohydrates in the mouth and produced lactic acid, which in turn dissolved the inorganic salts in the protective enamel of the tooth. The enamel was thought of as a rocklike, inert structure, a passive prey to its environment of bacteria, food debris and acid.

This straightforward explanation had to be amended at the turn of the century when it was found that the enamel is in part organic. From this fundamental discovery much of our current research activity still flows. We now know that the enamel shares with other biological tissues an all-pervading organic framework [see "The Skin of Your Teeth," by Reidar F. Sognnaes; Scientific American, June, 1953]. An important mechanism in the formation of cavities may, therefore, be the breakdown of the organic framework by the body's enzymatic processes. Investigations with radioisotopes show, furthermore, that the enamel interchanges its constituent elements in a two-way traffic with both the saliva and the bloodstream through the process of ion exchange. The turnover in the enamel is



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Many applications call for other properties in combination with wear resistance. Among Carborundum's many materials are refractories that also offer excellent heat shock resistance with sufficient hot strength to withstand 25 psi at 3128°F. Others provide unique resistance to corrosion as well as abrasion. These properties are but a few of those to be found in super refractories pioneered by Carborundum. Among them, you are almost certain to find answers to your refractory and high-temperature problems. For help, fill in and mail this coupon:

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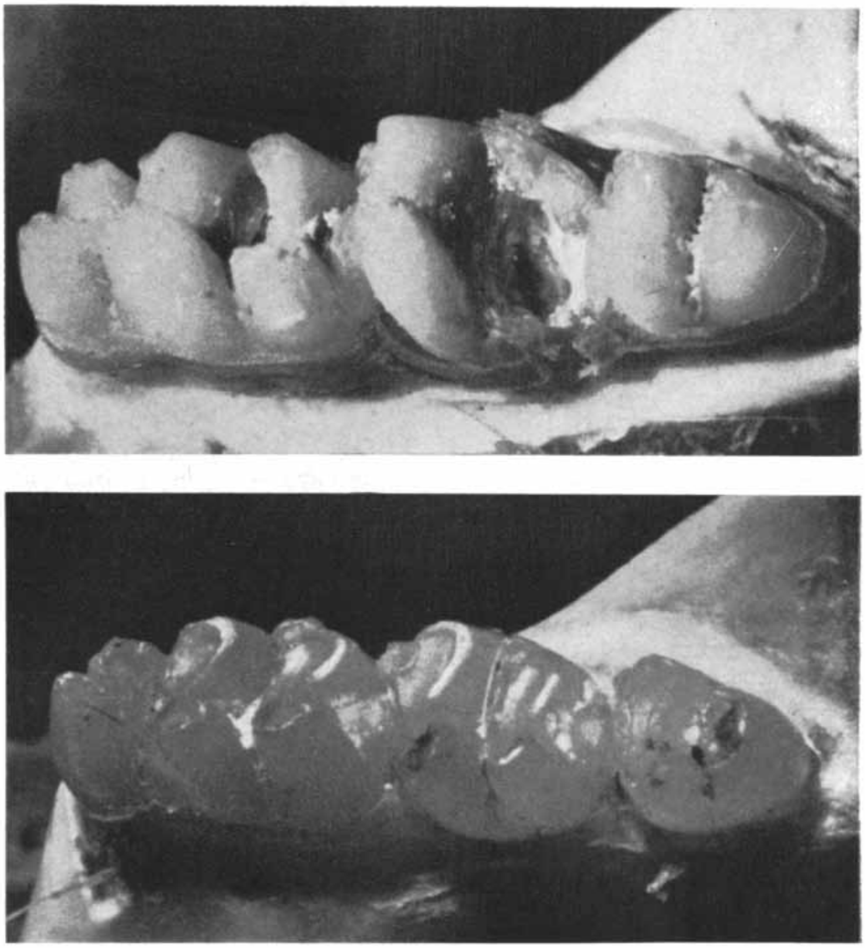
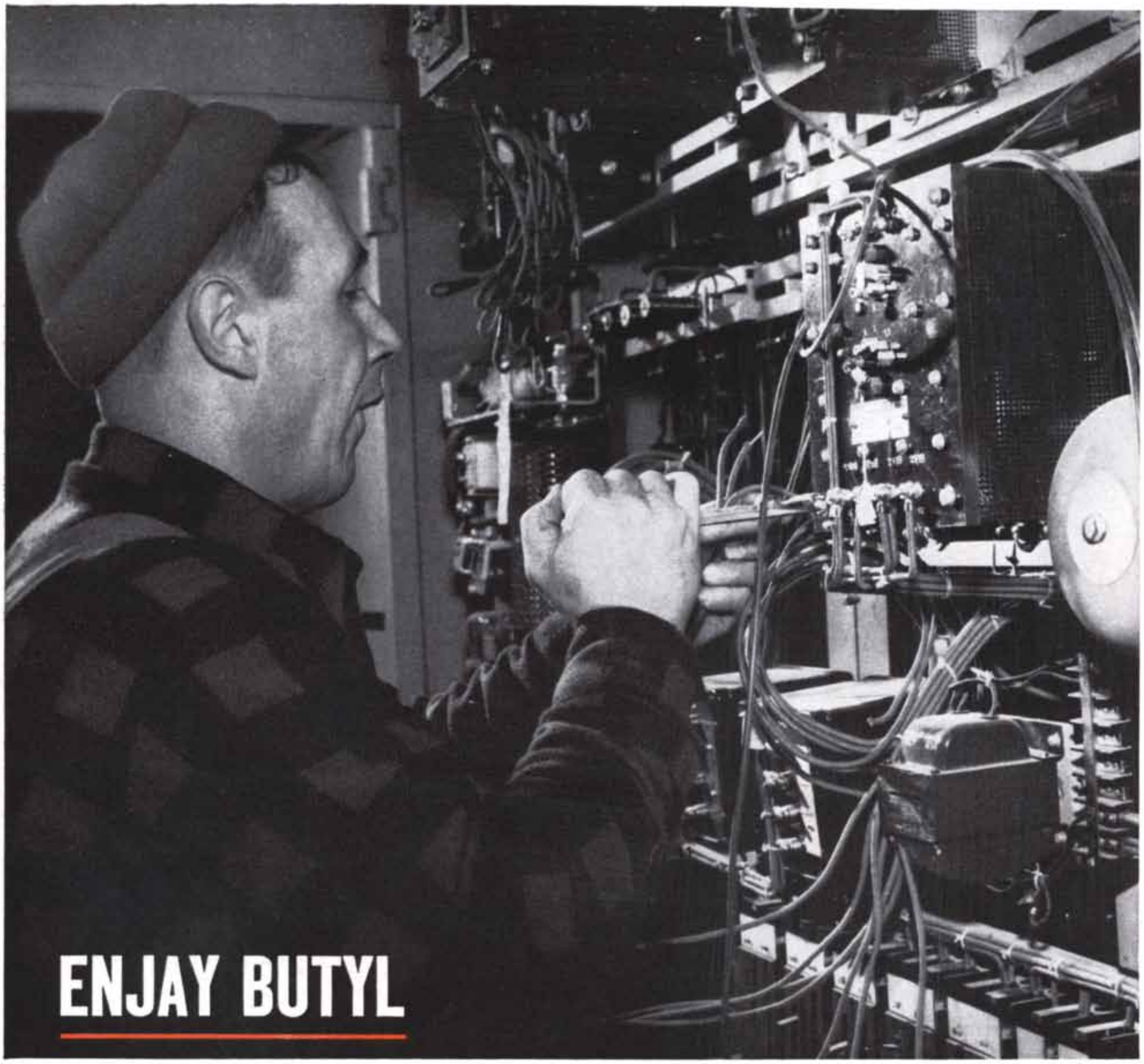
about one fifth that in the dentin; in the tooth as a whole it is much slower than it is in bone.

The give and take of material, proceeding simultaneously on both sides of the enamel, establishes an important biological relationship between the external environment of the tooth and its internal pulp, or "nerve." When the traffic is in equilibrium, the tooth's integrity is maintained; when the equilibrium changes, the tooth substance changes also, either for good or for ill. In the erupting teeth of children the exchange of certain elements, such as calcium and phosphorus, is 10 times more rapid than in teeth that have been in the mouth a long time. It is thought that the external exchange with the saliva in infant teeth is of special significance in establishing the quality of the enamel. Without doubt it is the higher rate of interchange in growing teeth that explains why the drinking of fluoridated water and the topical application of fluorine confer a higher degree of protection on children than on adults. In brief, the tooth is no longer regarded as a passive subject, but an actor in the contest of decay.

We have recently obtained conclusive experimental evidence that there can be no tooth decay without bacteria and a food supply for them. In germ-free laboratories at the University of Notre Dame and the University of Chicago, animals innocent of oral micro-organisms do not develop cavities. Where animals in normal circumstances average more than four cavities each, the germ-free rats show no signs of caries. At the Harvard School of Dental Medicine we have demonstrated the other side of the coin: that food debris also must be present. Rats that have plenty of bacteria in their mouths but are fed by tube directly to the stomach do not develop cavities. In a pair of rats joined by surgery so that they share a common blood circulation, the one fed by mouth develops tooth decay, the one fed by



MOLARS OF RATS raised in normal environment (*top*) and in a germ-free environment (*bottom*) are contrasted. Teeth at top are heavily decayed; the teeth at bottom are entirely free of decay. These pictures are from a study of Frank J. Orland of the University of Chicago and his colleagues, working in the germ-free laboratory of the University of Notre Dame.


ENJAY BUTYL

LOWER JAWS OF RATS, here enlarged about two diameters, contain three molars on each side. Tooth decay in the jaw at right resulted after 100 days of a decay-producing diet.

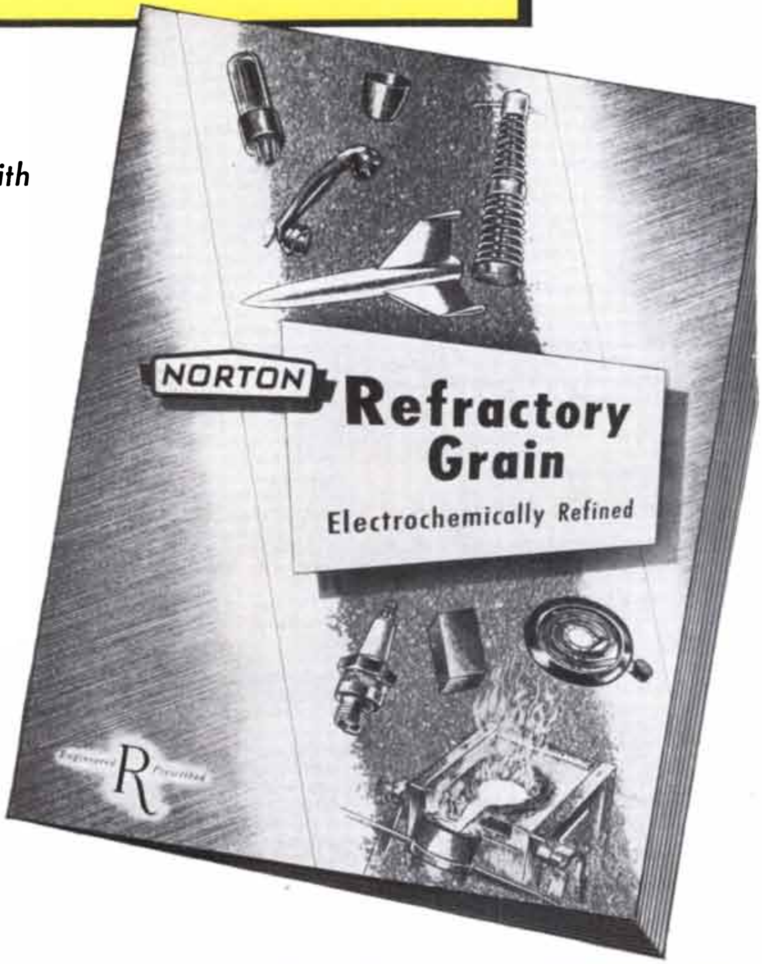
tube does not. None of this, to be sure, can be taken as an answer to the problem of preventing caries: in real life we cannot keep our teeth perfectly clean or our mouths completely free of bacteria.

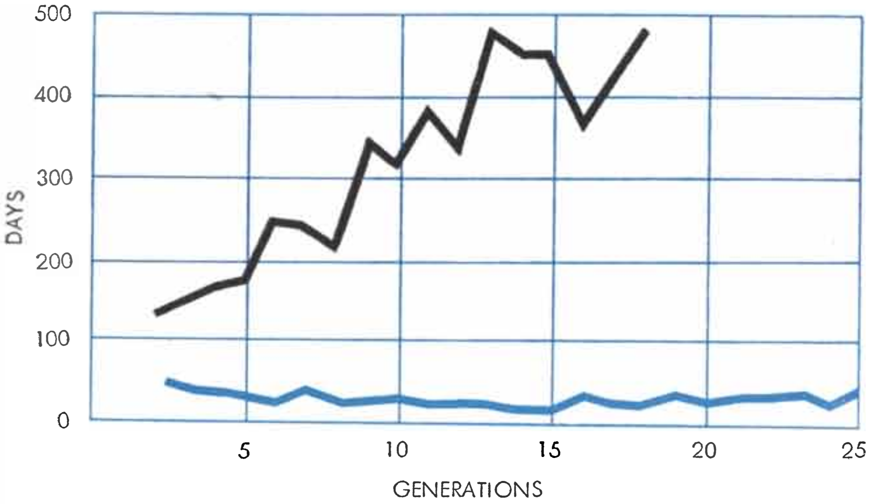
Another important factor in the oral environment is the saliva. Any disturbance in the production of saliva predisposes to decay. Interestingly enough, tube feeding offsets this effect completely. Even with the salivary glands removed by surgery, tube-fed rats were protected; but upon return to normal feeding they were subject to rampant caries. There is also some evidence that hormones play a part in tooth decay. Several laboratories have reported that castration of animals, especially males, reduces the incidence of caries. The relationship between hormones and the teeth is now under intensive study, especially by workers at Indiana University. It seems that hormones act both on the teeth themselves and on the oral environment through the saliva.

This brings us to the question of what we know about resistance to decay. For many years the major studies on this aspect of the problem have been devoted to nutrition, especially its role in the formation and growth of the teeth. More than 30 years ago it was observed that monkeys did not develop cavities, even when they were fed a sticky sugar mixture, unless they previously had suffered from multiple vitamin and mineral deficiencies. Work on this line has been followed up in many laboratories, and it is facilitated by the discovery that rats and hamsters can be made susceptible to caries at will by modification of their diet. Our own experiments have shown that the quality of nutrition plays a decisive role during the embryological and early infant phase of tooth development. We tested a synthetic diet, fulfilling all the known nutritional requirements and exceptionally rich in sugar. This was fed to some animals throughout pregnancy and the nursing period and to the offspring after weaning. The incidence of caries among these offspring was three or four times higher than among control animals whose nutrition before and after birth was supplied by ordinary laboratory rations.

Efforts have been made to find out what factors in the ordinary ration make for resistance. We burned the stock ration, reducing it to its minerals, and added this ash to the synthetic diet. It reduced the number of cavities per animal almost to the same low level as among the control animals. Trace elements were thus proved to be very important. Also significant was an experiment at the Massachusetts Institute of Technology which showed that food grown in New England confers less protection on laboratory animals than food grown in the soil and climatic conditions of Texas. Investigations at the National Institute of Dental Research in Bethesda, Md., indicate that the heat processing of food in some way affects the frequency of cavities. An important factor seems to be the destruction by heat of the amino acid lysine. A diet with a low phosphorus and high calcium content also seems to promote caries. In these experiments the teeth of the experimental and control animals were microscopically indistinguishable, despite marked differences in chemical composition and susceptibility to decay.

The most thought-provoking news in dental research today is coming from studies of hereditary factors. Groups at Michigan State University, the National Institute of Dental Research, the University of Rochester and our laboratory at Harvard have produced caries-resistant strains of rats and hamsters and have studied them for a number of years, in some cases for as long as 25 generations of the animals. Genetic factors can produce impressive contrasts in the incidence of dental disease, at least among laboratory animals. The Michigan State workers have bred susceptible rats which, on a decay-inducing ration, show


NORTON
Refractory Grain
Electrochemically Refined

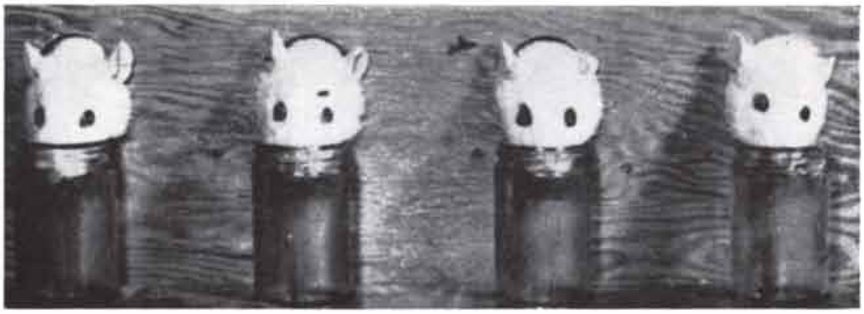


HEREDITARY DISPOSITION to tooth decay was accentuated by inbreeding in the genetic studies of H. R. Hunt and his colleagues at Michigan State University. In these two curves the average age at which the rats developed cavities is plotted against the generation after inbreeding had begun. A strain of rats resistant to decay became even more resistant (*black curve*). A strain susceptible to decay became slightly more susceptible (*colored curve*).

caries as early as the 35th day after birth, and resistant rats which on the same ration do not develop the first cavity until 550 days after birth. Investigators are now exploring the factors through which heredity works to make the animals susceptible or resistant. They have found, for one thing, that susceptible rats are much more likely to harbor certain microorganisms in their mouths than resistant rats are. They have also noted that the molars of susceptible strains of rats have deep, narrow grooves, where food debris can collect.

In the long run it is likely that the deeper secrets of dental health will turn out to lie within the teeth themselves and not merely in the environment. While we may learn to improve the quality of our teeth, perhaps the ultimate lesson to be learned from dental research is how to live with our environment, unfavorable as it may be. For unless we live in germ-free tanks and feed ourselves by stomach tubes, a clean tooth never will exist. As we improve our understanding of the mechanism of decay we shall learn to prevent it through our diet and drinking water and by topical application of chemical agents, as well as by the familiar methods of oral hygiene.

Meanwhile there is nothing to suggest that the tremendous rise in tooth decay throughout the world during the past few centuries has leveled off. With increasing life expectancy dental ills are going to become more and more widespread and costly, dissipating time and energy and causing pain, distraction and apprehension among a population which in other respects will be growing healthier. Nothing short of a broad and strongly supported scientific attack is likely to bring this problem under control before it gets completely out of hand.



DROOLING ANESTHETIZED RATS provided saliva for Hunt and his colleagues. They analyzed saliva from resistant and susceptible rats to determine whether there are chemical differences which may explain the variations in hereditary predisposition to tooth decay.

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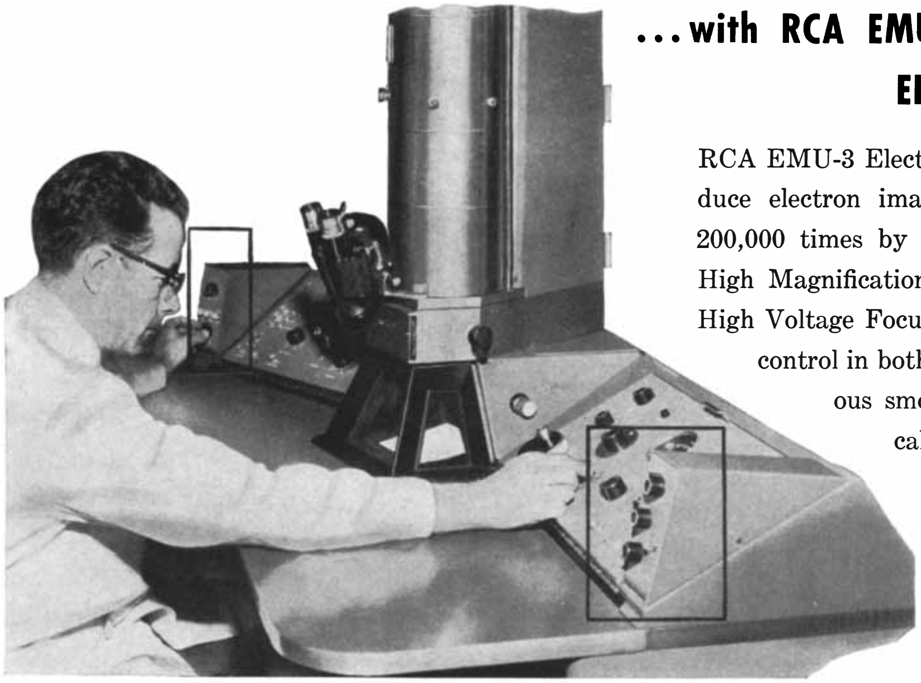

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The Indestructible Hydra

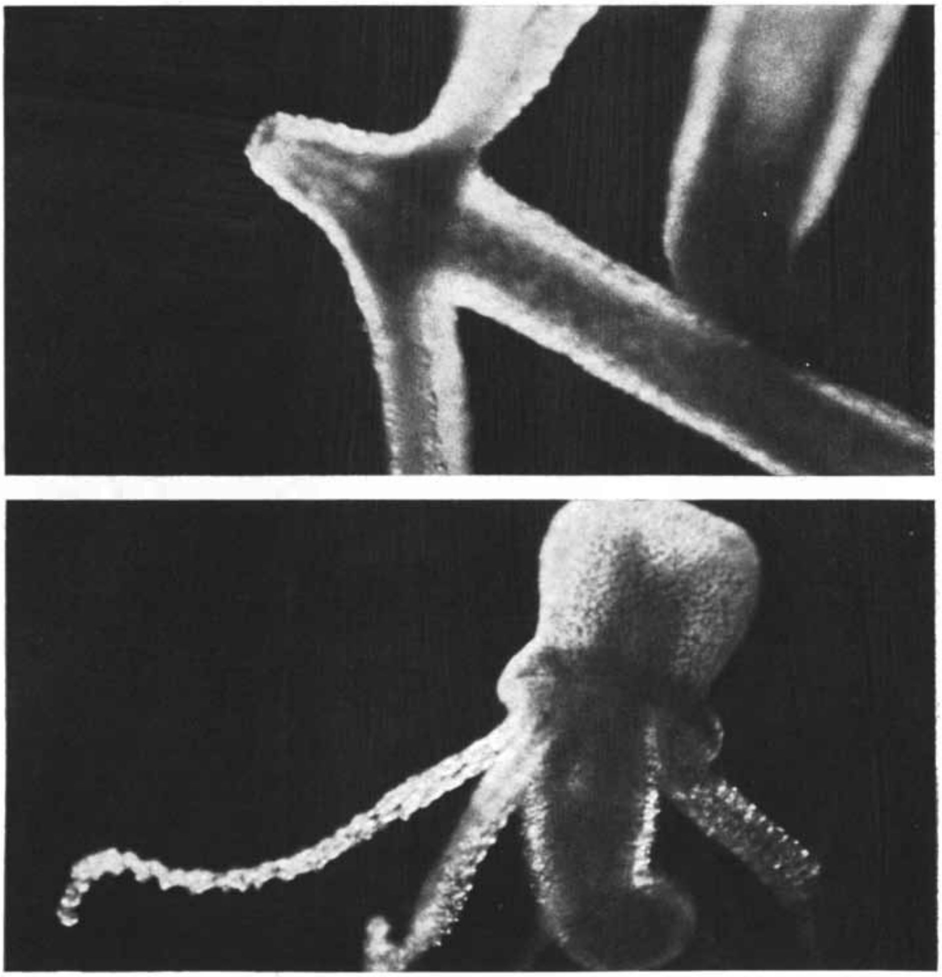
This tiny fresh-water animal can be cut into as many as eight pieces, each of which then grows into a complete individual. Recent studies have illuminated how it grows and regenerates

by N. J. Berrill

The hydra is an improbable creature which our biology textbooks have made familiar—if not quite believable—to us all. Its name comes, of course, from the nine-headed Greek monster Hydra, which grew two new heads in place of every one that was cut off. The tiny real hydra, though anything but fearsome (except perhaps to the water fleas upon which it feeds), can do much more than its mythical namesake. No matter how you slice it up or manhandle it, it comes to life again; indeed, it is the most irrepressible of all known multicelled animals. This makes the little hydra an endlessly fascinating research subject. It has been subjected in recent years to some remarkable experiments which throw light on general questions concerning the growth and form of living things.

Hydra is an inconspicuous inhabitant of reedy ponds and slow-running waters. It was discovered by Anton von Leeuwenhoek among the tiny "animalcules" he found on looking through the first microscope. The slender creature is about the size of a bit of coarse thread a quarter of an inch long. It has an extremely simple structure—little more than a tube with a wall made up of two layers of tissue. The foot end of the tube, where the animal attaches itself to a weed, is closed; the head end has a small mouth-opening and a group of tentacles.

The first experimenter to discover the recuperative powers of hydras was an 18th-century Swiss, one Abraham Trembley, the poorly paid tutor of the children of the Comte de Bentinck in Holland. He took notice of these slender organisms in the ponds of the count's garden. Because of their green color, he first took them to be plants, but when he saw them swallow tiny crustaceans that collided with their tentacles, he decided they must be animals. Trembley, a man consumed by the scientific itch, cut some hydras in two to see what would happen. Each half grew into a whole animal again! This was somewhat confusing, but Trembley could not let well enough alone: he went on to manhandle hydras in every way he could think of. He would cup the animal in a drop of water in his hand and operate on it with a needle or a piece of horsehair. His dexterity was remarkable; with all our



HYDRA TURNS ITSELF INSIDE OUT in these photographs made by Roman Vishniac in the laboratory of W. F. Loomis in Greenwich, Conn. Placed in a "tasty" fluid, the hydra

modern instruments, experimenters today have improved little on Trembley's skill in handling hydras.

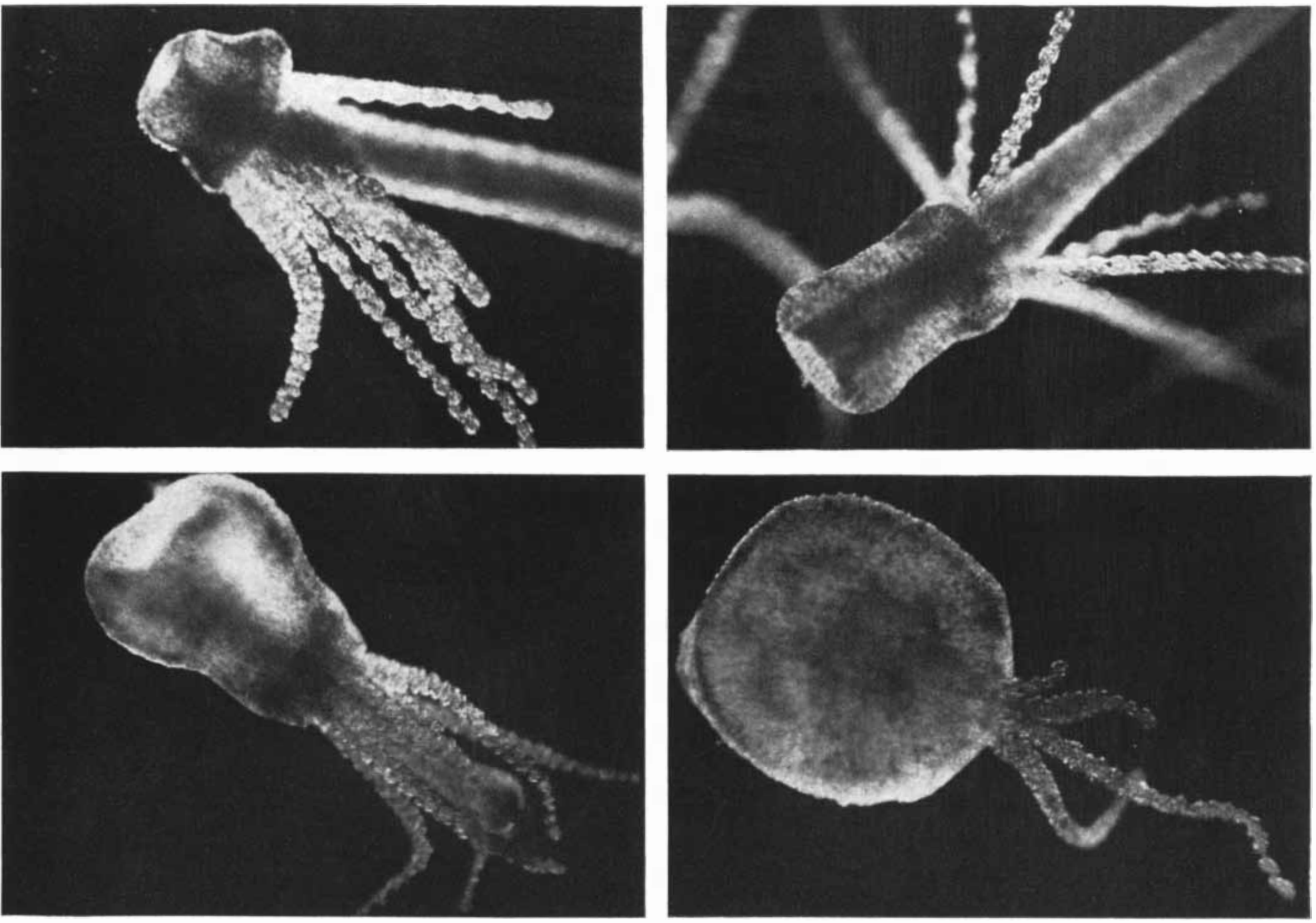
What he found was this. When a hydra was cut into as many as eight pieces, each piece could still regrow into a complete hydra. An animal sliced lengthwise, with a connection left at the bottom end, would speedily fuse together again if the slips were put together, or would form two Siamese-joined hydras if they were kept apart. If a hydra's body was amputated, the head quickly grew a new body. Trembley found that even when he turned a hydra inside out, by inserting a horsehair into its body cavity and then delicately peeling off the body like a sock, the animal lived and functioned in a perfectly normal way.

Trembley published an account of his extraordinary experiments in 1744, and it immediately caught the attention of enlightened men throughout Europe. The whole thing was difficult to believe, but when René Antoine Ferchault de Réaumur, the foremost scientist of France, and the president of the Royal Society in England both confirmed Trembley's discoveries by repeating his experiments, everyone took up the investigation. The Duke of Richmond went to Holland on behalf of the Royal Society to observe Trembley at work. The leading members of the learned societies of England and the Continent experimented daily on hydras, and they exchanged their regenerated animals by careful post as precious gifts.

In our more sophisticated century the hydra has been a favorite laboratory subject of biologists studying growth and form. They have chopped up the animal and put the pieces together in many different ways in an effort to see how living tissue develops and takes shape—as one might take a watch apart to see how it works. The procedure is always fascinating, but so far most of the experiments have merely told us more about the wonderful feats the hydra is capable of performing, without enlightening us a great deal on how it manages to perform them.

The little hydra offers all sorts of interesting questions for a biologist. A hydra can reproduce either sexually or by putting out buds that grow into offspring: what determines which course it will follow? How much punishment can a hydra take? Is it a totally versatile mass of protoplasm, or are there critical parts that control its growth? Experimenters have looked into many such questions.

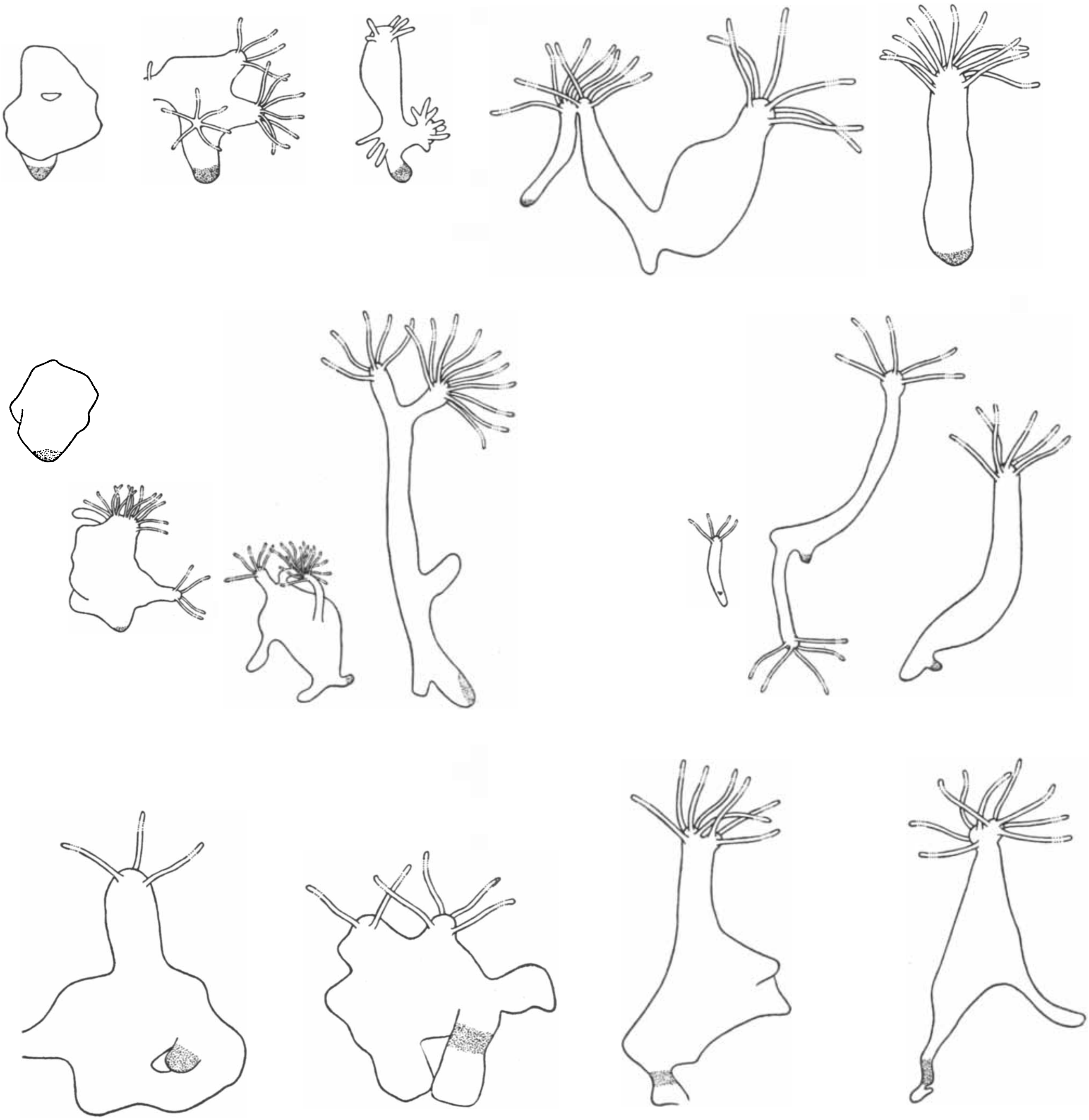
What happens when a hydra is turned inside out? Usually it dies, but it can survive in one of two ways. Often it simply turns itself right side out again, by dint of writhing, stretching and unrolling. Philip A. Orkin of the University of Aberdeen was even able to make hydras turn themselves inside out! He put them in a flat glass dish plated with yeast. The hydras, finding this a tasty food, bent over and spread their mouths over the yeast. Often the mouth spread out so wide that its rim snapped back



opens its mouth (*first photograph*). The rim of the mouth then folds back over its body, exposing more of its interior to the fluid (*second photograph*). The process continues (*next three photographs*) until the animal is completely inside out (*last photograph*).

over the body; then the inner body-lining, greedily reaching for the yeast, gradually rolled out until the animal was almost completely everted. Later the hydra reversed the process and recovered its normal condition. But everted hydras have been known to live and thrive without bothering to turn themselves right side out. R. L. Roudabush of Iowa State College reports that in these cases the two layers of tissue—the turned-in outer skin and the turned-out inner layer—get back to their normal positions by cross-migration of their cells: sliding past each other singly and in groups, the cells of epidermis move out to where they belong and those of the inner lining move in, until both layers are reconstituted in their proper places. Just how the cells "know" where they are supposed to be is a mystery.

A long time ago Florence Peebles, the versatile and illustrious biologist who did a great deal of experimental work at the Marine Biological Laboratory in Woods Hole, Mass., found that a bit of hydra tissue as small as six thousandths of an inch in diameter could grow into a complete hydra. More recently Emma Papenfuss of the Johns Hopkins University experimented in dissecting hydras and watching what happened when fragments were put together. She discovered that a new hydra could not be regenerated by a piece of inner or outer tissue alone; both had to be supplied. The frag-



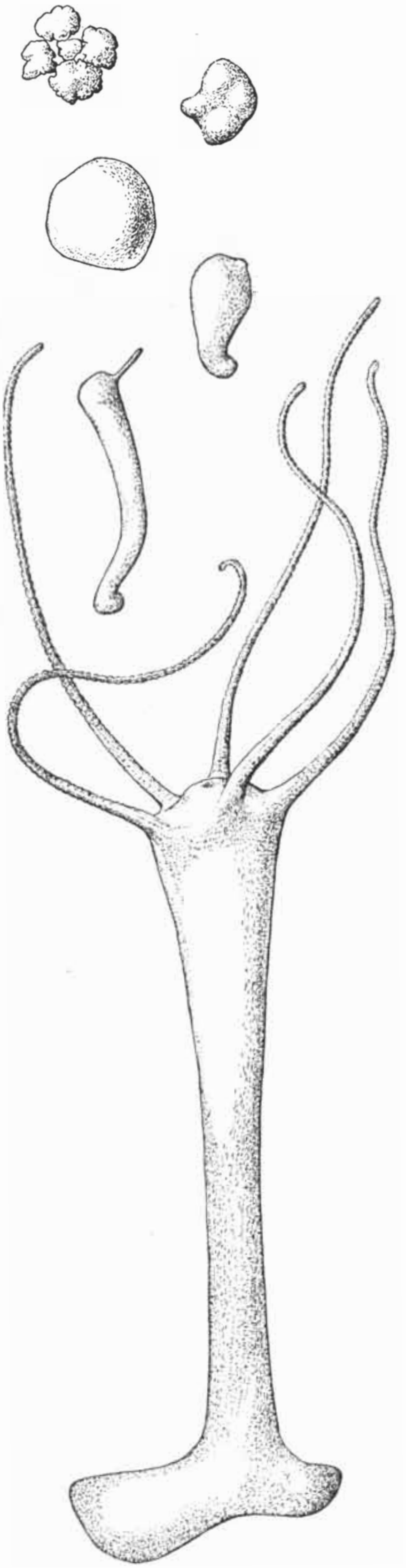
HYDRAS REGENERATED FROM FRAGMENTS in experiments by Emma Papenfuss of Johns Hopkins University always regrew a foot from stained foot tissue (*shaded*). The four series (*two series are in the second row*) also illustrate the merging of excess parts.

ments first united to form a two-layer sheet; then the sheet rolled up to form a cylinder, with the epidermis on the outside; finally the cylinder ends grew a head and a foot, respectively. What could be simpler—or harder to explain!

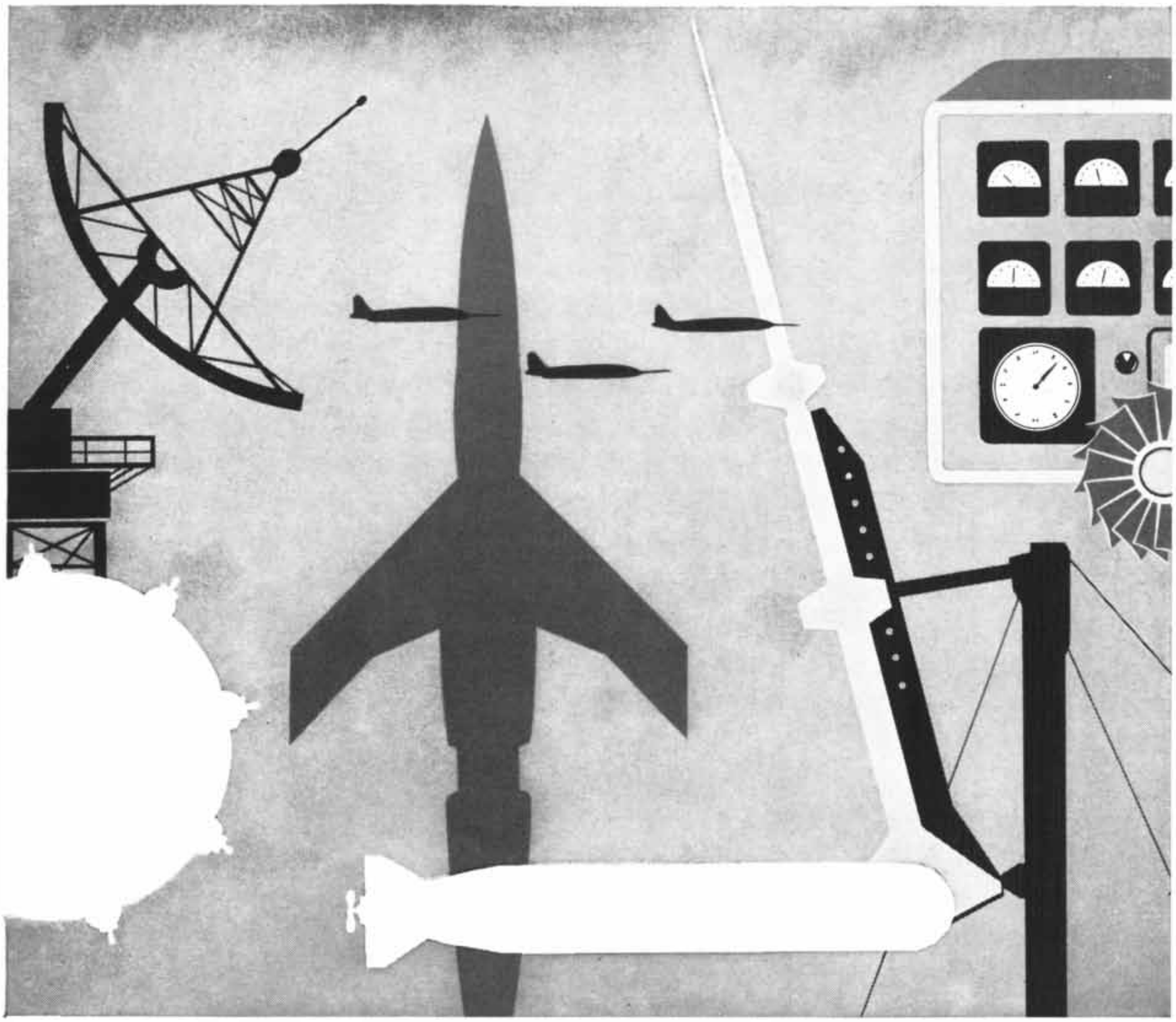
Dr. Papenfuss cut off a hydra's foot, stained it with methylene blue, chopped up the rest of the body and then mixed all the fragments together. In every case the foot wound up as a foot in its proper place in the regenerated hydra. When she put together the chopped-up fragments of several individuals, the heads joined up with heads, feet with feet, tentacles with tentacles. Like has a striking affinity for like, even if the result is an excess of feet or tentacles. Eventually the parts coalesced: a regenerated hydra's two heads became one, and similarly it was reduced to a single foot and to the normal number of tentacles.

H. W. Chalkley of the National Cancer Institute in Bethesda, Md., performed some much more drastic experiments. He decapitated about 20 hydras and minced up their trunks into a jelly-like mush. Then he distributed bits of this paste in a number of little conical holes bored in a lucite block. The block was covered with agar and immersed in salt water. After 24 hours Chalkley took the cones of hydra paste (now fused) out of their molds. Each promptly rolled up into a ball, and within a week had grown into a hydra, complete with head, or heads, and tentacles. The largest individual had four heads: it worked out that the number of heads was roughly proportional to the surface area of the globules of tissue from the various-sized molds.

Paul Brien and co-workers at the University of Brussels have carried out in the last few years the most intensive and systematic experiments yet performed on hydras. Brien has been trying to find out just how a hydra grows and maintains its form. Suspecting that its growth stems from an active center in the head region, he undertook to label the tissue of the neck and follow its growth migration. Brien first tried sticking a bit of fine silver wire into the neck; when the hydra insisted on expelling this foreign object, he decided that he would have to mark the tissue with dye. This proved to be very difficult, for a hydra is continually stretching and contracting its body (a specimen only one tenth of an inch long can stretch out to half an inch). Brien resorted to a delicate operation, taking advantage of the hydra's regenerative ability. He stained one hydra with a blue dye, cut



STAGES OF REGENERATION are shown in these drawings based on the work of Papenfuss. Bits of tissue (*top*) coalesce, form a flat sac and then a cylinder. One end gives rise to a foot; the other, tentacles.



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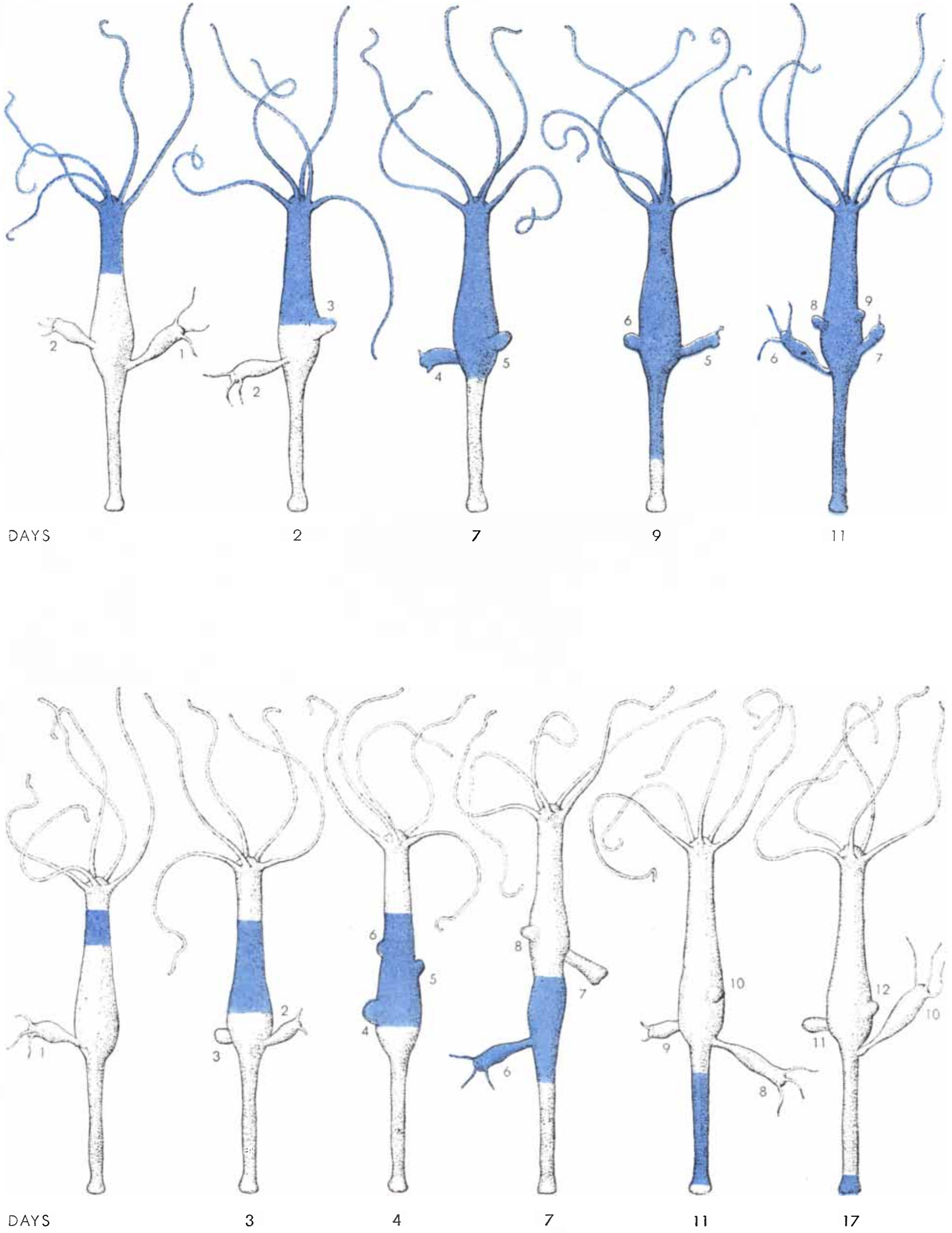


PARTLY COLORED HYDRAS were made by Paul Brien of the Free University of Brussels by combining parts of stained animals with unstained ones. The top row shows the replacement of trunk tissue by the stained tissue growing down from the head. Buds are numbered in order of appearance. The bottom row shows the decrease in growth rate as tissue moves downward from neck to foot.

it in two and grafted the head end onto the headless trunk of another, unstained individual. To make sure that the two halves would fuse, he had to thread both on a silver wire and press them together. After four hours they had fused sufficiently so that he could remove the wire. Brien then had a hydra with a blue head and a naturally colored trunk and foot. To make the color demarcation sharper, he sometimes grafted a red-stained half to a blue-stained half, or placed a red neck between an unstained trunk and unstained head.

Stained cells do not pass the dye along from cell to cell. Therefore any movement of the dye through the body represents the growth or migration of tissue. Brien found that the dyed tissue near the head rapidly migrated toward the hydra's foot. Within about a week it had reached the mid-trunk, where the hydra puts forth the buds that are to become its offspring. In another week the dyed cells had moved all the way down to the animal's foot.

The conclusion was clear. The stained tissue had been shunted down to the foot by new growth originating in or near the head. By this experiment and many similar ones Brien demonstrated that the hydra continuously produces new tissue in a zone of rapid growth just below the tentacles; that the tissue travels down toward the animal's foot, still growing but at a slowing rate, and that after it has arrived at the base the aged tissue disappears. In short, the hydra's body is like a candle flame, which is continually fed at the combustion source and continually dies at the flame tip. The substances of a flame are fleeting, but the flame itself keeps its characteristic form and structure. Just so a hydra maintains a certain size and shape, although the material of its body lives only briefly.

In the hydra the wick, so to speak, is its head. If we cut off the head and transplant it in the side of another hydra, a whole new hydra will bud and grow out of the host. Conversely, if a hydra's head loses its vitality, the animal will die, as a candle flame expires when the wick burns out. When generation of new tissue by the head ceases, the hydra's body slowly collapses into a little white mound and eventually disappears.

The hydra exhibits, perhaps more dramatically than any other creature, the dynamic process of continual birth and death which is the essence of every living thing. Undoubtedly biologists will continue to learn from this fascinating and spectacular little animal for centuries to come.

MATHEMATICAL GAMES

More about complex dominoes, plus the answers to last month's puzzles

by Martin Gardner

In the year since this department was inaugurated, it has received more letters about one mathematical recreation than any other. This recreation is the "pentomino" problem, discussed here in May. Where a domino is made up of two adjoining squares, a pentomino consists of five squares. There are exactly 12 kinds of pentomino. These can be combined in many ways with a square tetromino (four squares in square formation) to form a checkerboard with eight squares on each side. Readers were challenged to construct such a checkerboard with: (1) the square tetromino exactly in the center, (2) the square tetromino in one corner.

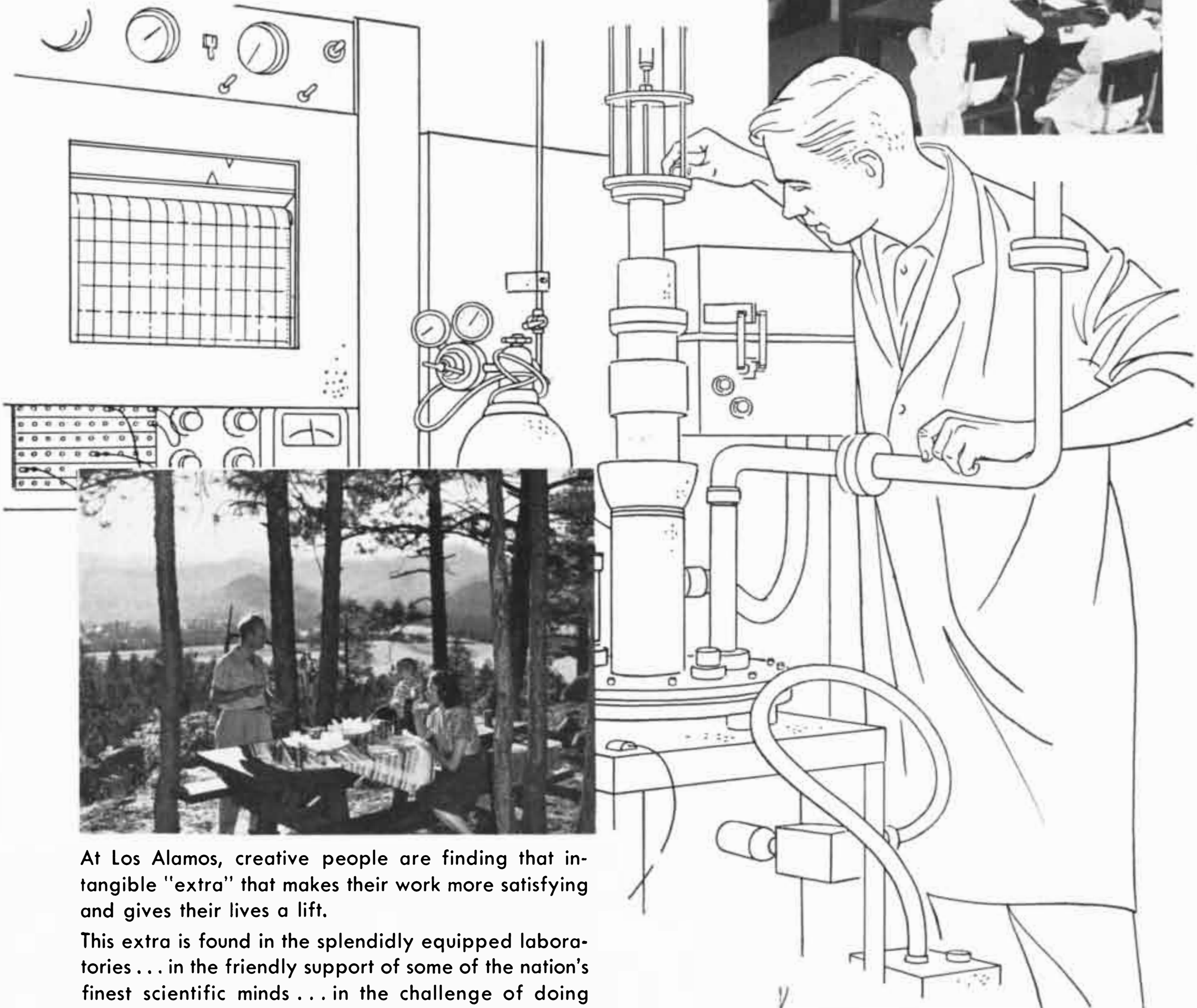
Hundreds of correspondents sent in widely varying solutions. Many testified to the problem's strange fascination and to the pleasure they experienced when they finally solved it, often after several hours of intense concentration. One reader boasted of having acquired great skill in fitting together the pieces by becoming intimately acquainted with the "personality" of each. Others complained that they had been driven almost crazy by the stubborn refusal of the pentominoes to adjust to desired contours.

Several readers called attention to an obscure British publication, *The Fairy Chess Review*, in which dozens of unusual pentomino problems have been published during the past 20 years. (Fairy chess is chess that deviates from the standard game by using different rules, boards or pieces.) Solomon W. Golomb, senior research mathematician in the Jet Propulsion Laboratory of the California Institute of Technology, permitted us to read an unpublished paper on pentominoes. This paper brings up to date his article "Checker Boards and Polyominoes," published in a mathematical journal in 1954, when Golomb was a 22-year-old graduate student at Harvard University. The following material summarizes some highlights of Golomb's later paper, plus parallel but independent developments recorded in *The Fairy Chess Review*.

It was Henry Dudeney, the British puzzlist, who first proposed the pentomino checkerboard problem. It appeared in his book *The Canterbury Puzzles*, published in 1908. Dudeney's single solution had the square tetromino at the side of the board. One is led to ask: Can the problem be solved with the square in any position on the board? T. R. Dawson, founder of *The Fairy Chess Review*, was the first to devise a delightfully simple way of demonstrating that the answer is yes. In his three-part solution, depicted in the illustration at left on page 128, the square tetromino (2 × 2) is combined with an L-shaped pentomino to make a larger square (3 × 3). By rotating the large square, the 2 × 2 square can be brought to four different positions in each of the three configurations. Since the entire checkerboard can be both rotated and reflected, it is easy to see that the small square can be placed at any desired spot on the board.

If the 2 × 2 square is discarded and four disconnected squares left blank, the problem can still be solved in a variety of artistic ways, a few of which are shown in the illustration at right on page 128. It is also possible to fit the 12 pentominoes to form rectangles that are 6 × 10, 5 × 12, 4 × 15 and 3 × 20. The first three are shown on page 129. The 3 × 20 rectangle, by all odds the most difficult, is left for the interested reader to construct. The solution will be given in this department next month.

Raphael M. Robinson, professor of mathematics at the University of California, recently proposed what he calls "the triplication problem." You select one pentomino, then use nine of the remaining ones to form a large scale-model of the chosen piece. The model will be three times higher and wider than the small one. Joseph B. Tucker, rector of Trinity Episcopal Church in Clarksville, Tenn., independently hit on the triplication problem after reading this department's discussion of pentominoes. He



sent in many excellent solutions, including the two shown in the top illustration on page 130.

What is the minimum number of pentominoes that can be placed on a checkerboard in such a way that it is impossible to place any of the remaining pentominoes on the board? This intriguing question is asked by Golomb, and he says the answer is five. The bottom illustration on page 130 shows one such configuration. This problem suggested to Golomb a fascinating competitive game that can be played on a checkerboard with large cardboard pentominoes cut to fit accurately over the board's squares. (The reader is invited to make such a set, not only to enjoy the game, but also to solve pentomino problems and create new ones.)

Two or more players take turns in choosing a single pentomino and placing it wherever they wish on the board. The pieces have no "top" or "bottom" faces. As in all problems mentioned in this article, asymmetrical pieces may be used with either side up. The first player who is unable to place a piece is the loser.

Golomb writes: "The game will last at least five and at most 12 moves, can never result in a draw, has more possible openings than chess, and will intrigue players of all ages. It is difficult to advise what strategy should be followed, but there are two valuable principles:

"1. Try to move in such a way that there will be room for an even number of pieces. (This assumes only two are playing.)

"2. If you cannot analyze the situation, do something to complicate the position, so that the next player will have even more difficulty analyzing it than you did."

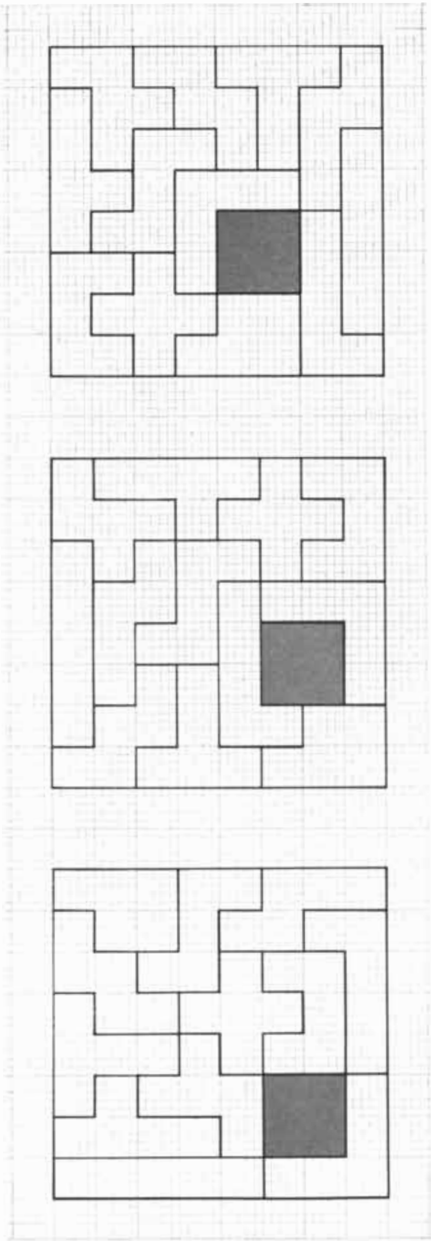
Hexominoes, groups of six adjoined squares, have exactly 35 distinct varieties. There are 109 different heptominoes (seven-square pieces). Golomb says that no one has yet been able to obtain a formula for the exact number of n-ominoes as a function of n.

Since the 35 hexominoes have a total area of 210 squares, one thinks immediately of arranging them to form a rectangle which could be 3 × 70, 5 × 42, 6 × 35, 7 × 30, 10 × 21 or 14 × 15. I seriously considered offering $1,000 to the first reader who succeeded in constructing one of these six rectangles, but the appalling thought of hours that might be wasted on the challenge forced me to relent. All such efforts are doomed to failure. Golomb's proof of this is a striking example of the use of two powerful tools of combinatorial geometry. This is a little known branch of mathematics, though it has many practical applications to engineering design problems involving standard components that must be fitted together in the most efficient manner. The tools are: (1) the use of contrasting colors to aid one's mathematical intuition, and (2) the principle of "parity check" based on the combinatorial properties of odd and even numbers.

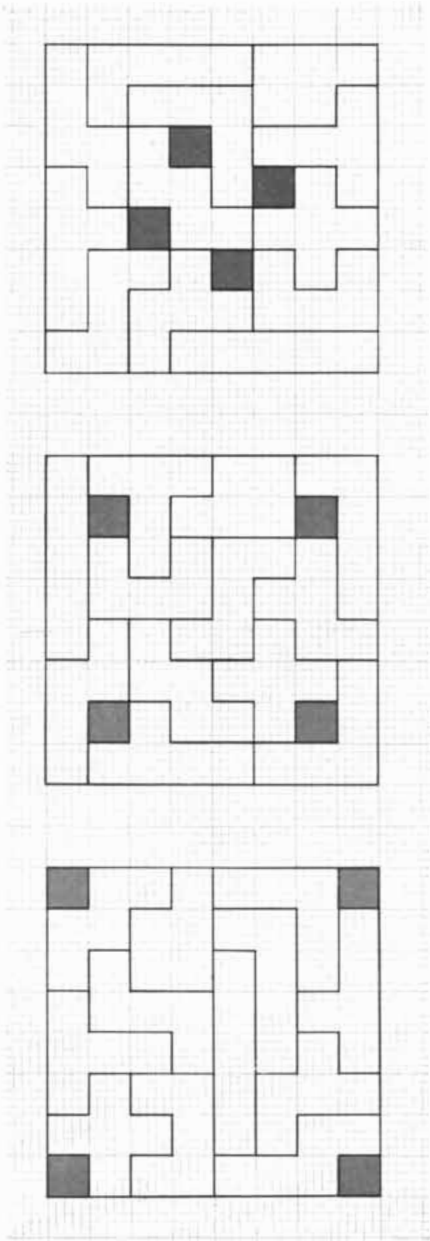
We begin the proof by coloring our desired rectangles with alternating black and white squares like a checkerboard. In each case the rectangle clearly must contain 105 black squares and 105 white—an odd number for each.

Turning our attention to the 35 hexominoes, we discover that 24 of them will always cover three black squares and three white—an odd number for each. There is an even number of these "odd hexominoes," and since even times odd is even, we know that all 24 of them will cover an even number of squares of each color.

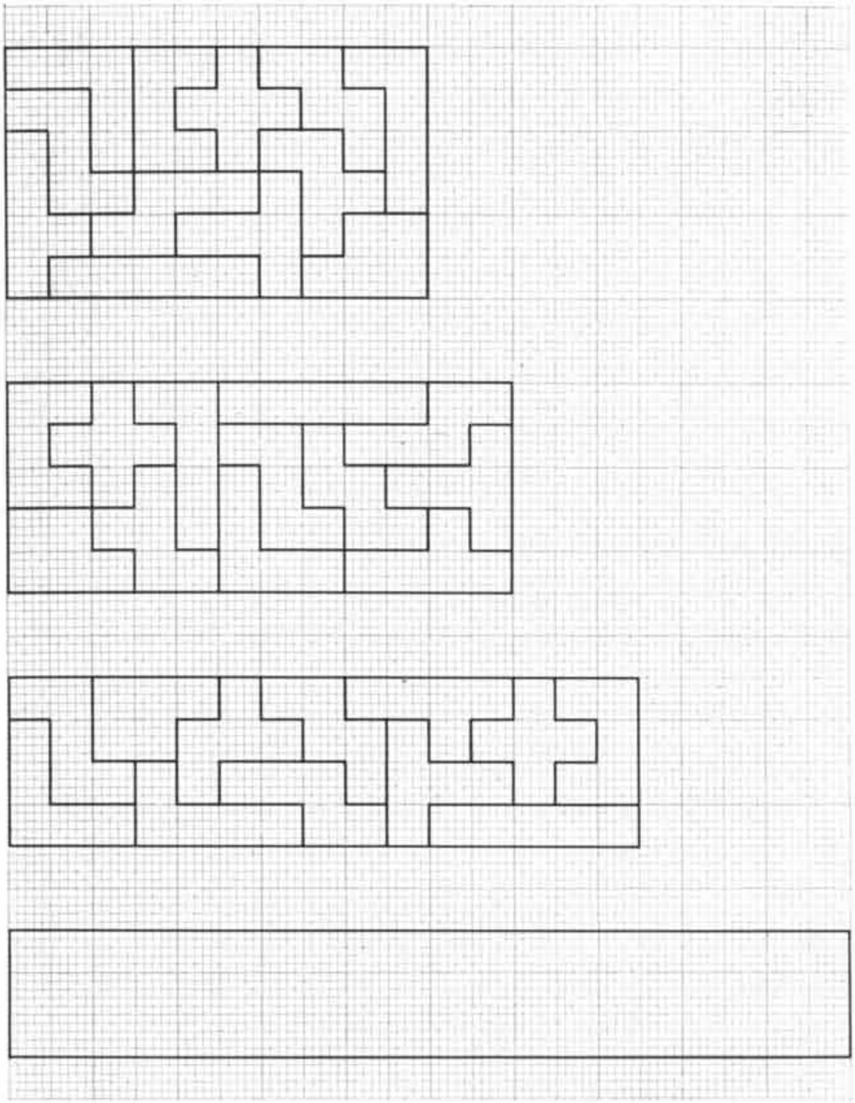
The remaining 11 hexominoes are of such a shape that each must cover four squares of one color and two of the other—an even number for each. There is an odd number of these "even hexominoes," but again, since even times odd is even, we know that these 11 pieces also will cover an even number of squares of each color. (The illustrations on pages 132 and 134 divide the 35 hexominoes into even and odd



T. R. Dawson's pentomino solution



Solutions with four blank squares



Four rectangles can be made with the 12 pentominoes. The 3 × 20 rectangle is left blank

groups.) Finally, since even plus even is even, we conclude that the 35 hexominoes together will cover an even number of black squares and an even number of white squares. Unfortunately each rectangle contains 105 squares of each color. This is an odd number. No rectangle, therefore, can be covered by the 35 hexominoes.

"There is a lesson in plausible reasoning to be learned from these problems," Golomb concludes. "Given certain basic data, we labor long and hard to fit them into a pattern. Having succeeded, we believe the pattern to be the only one that 'fits the facts'; indeed, that the data are merely manifestations of the beautiful, comprehensive whole. Such reasoning has been used repeatedly in religion, in politics, even in science. The pentominoes illustrate that many different patterns may be possible from the same 'data,' all equally valid, and the nature of the pattern we end up with is determined more by the shape we are looking for than by the data at hand. It is also possible that for certain data [as in the hexomino problem explained above], no pattern of the type we are conditioned to seek may exist."

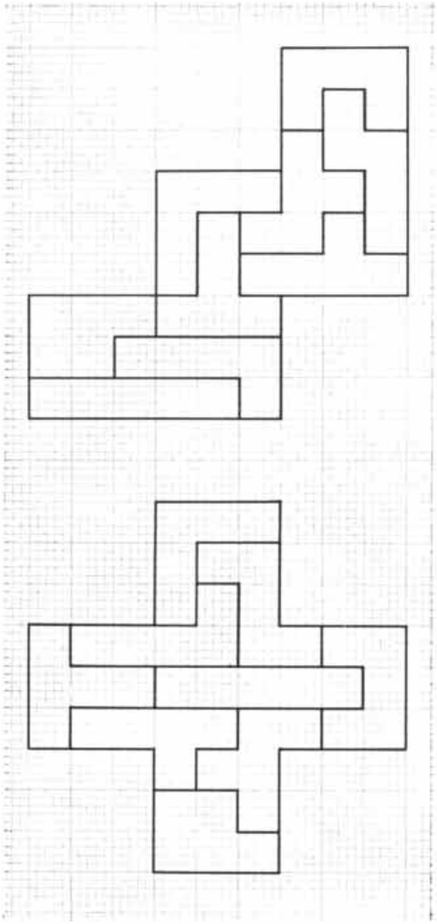
The answers to the nine "brain teasers" in this department for last month are given without further ado:

1.

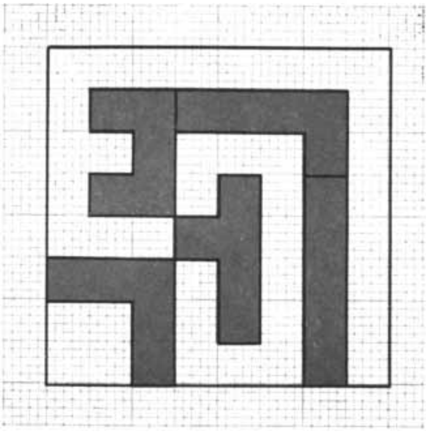
The six cigarettes are placed as shown at left at the top of page 136, each touching the other five.

2.

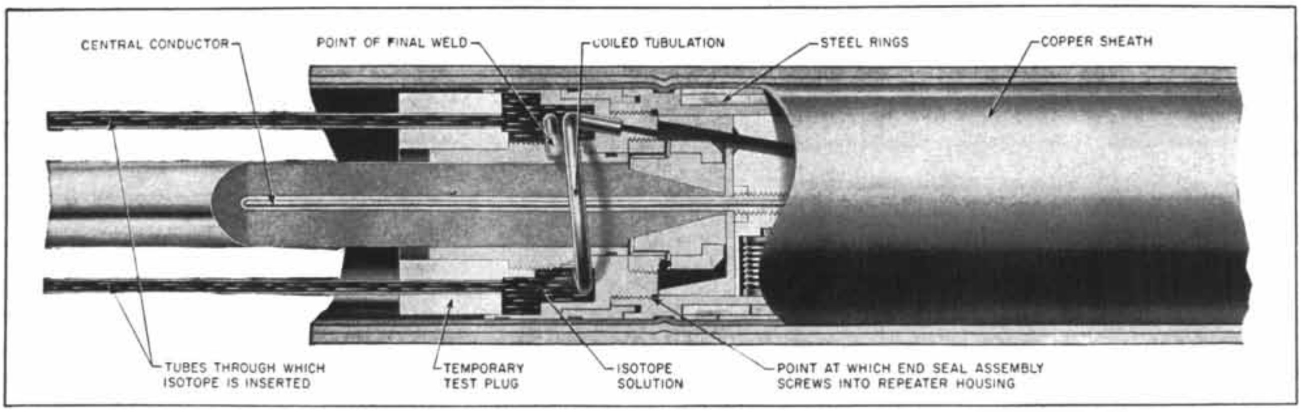
When the ferryboats meet for the first time [*top of illustration at bottom* *of page 136*], the combined distance traveled by the boats is equal to the width of the river. When they reach the opposite shore, the combined distance is twice the width of the river; and when they meet the second time [*bottom of illustration*], the total distance is three times the river's width. Since the boats have been moving at a constant speed for the same period of time,



Solutions of the "triplication problem"



No other pentominoes can be added here



END SEAL AREA OF TRANSATLANTIC CABLE REPEATER

Radioisotopes used in unique test of repeaters for transatlantic telephone cables

Flexible repeaters (voice amplifiers) for the new trans-oceanic telephone cables are expected to withstand ocean-bottom pressures of up to 6,000 psi for many years without developing leaks. At Western Electric's specially designed shop in Hillside, N. J., where the 36-channel carrier repeaters are made, engineers literally build perfection into the product, then enclose it in steel rings and a tube-like copper sheath. Before the completed repeaters are spliced to connecting cable links, they have to be sealed positively against the entry of sea water. This involves a series of welding and brazing operations.

But after the final point of welding and brazing, when there is no longer any means of access to the interior of the repeater unit, how could the engineers really be sure that the repeater would not leak under pressure at 2,300 fathoms?

The answer to this question is embodied in one of the most unusual of the many new and intricate testing procedures developed around the manufacture of the precision repeaters. It utilizes a solution of radioisotope "cesium 134." Here is how the test is conducted:

After the last of the series of welding and brazing closure operations, the ends of the copper repeater housing are filled with a solution of the isotope which is held against the seal by means of a temporary test plug fixture. The repeater is then placed in a test cylinder and hydraulic pressure of 7,500 psi is applied and transmitted to the isotopic solution. After 60 hours under this pressure, the radioactive solution is drained off, the repeater is washed and finally examined by means of a Geiger counter. If the Geiger count reveals that any of the isotope penetrated the end seal area, the repeater is rejected.

Geiger Counter is used to determine that no radioisotopes have penetrated into the interior of the repeater unit.

In practice, of course, the test is far more involved. For example, the washing of the seal calls for 60 different operations, each precisely timed. Also, to make certain that the production people know exactly what to do and when to do it, instructions recorded on magnetic tape by a Western Electric engineer are played back to operators over a loud speaker.

The perfection of this unusual testing technique is another example of the wide-ranging engineering activity at Western Electric . . . where engineers constantly search out and adapt the latest advances of science. It is an example, as well, of the exacting standards that govern the manufacture of Bell telephone equipment – an important factor in the dependability of the telephone service provided by Bell System operating telephone companies.

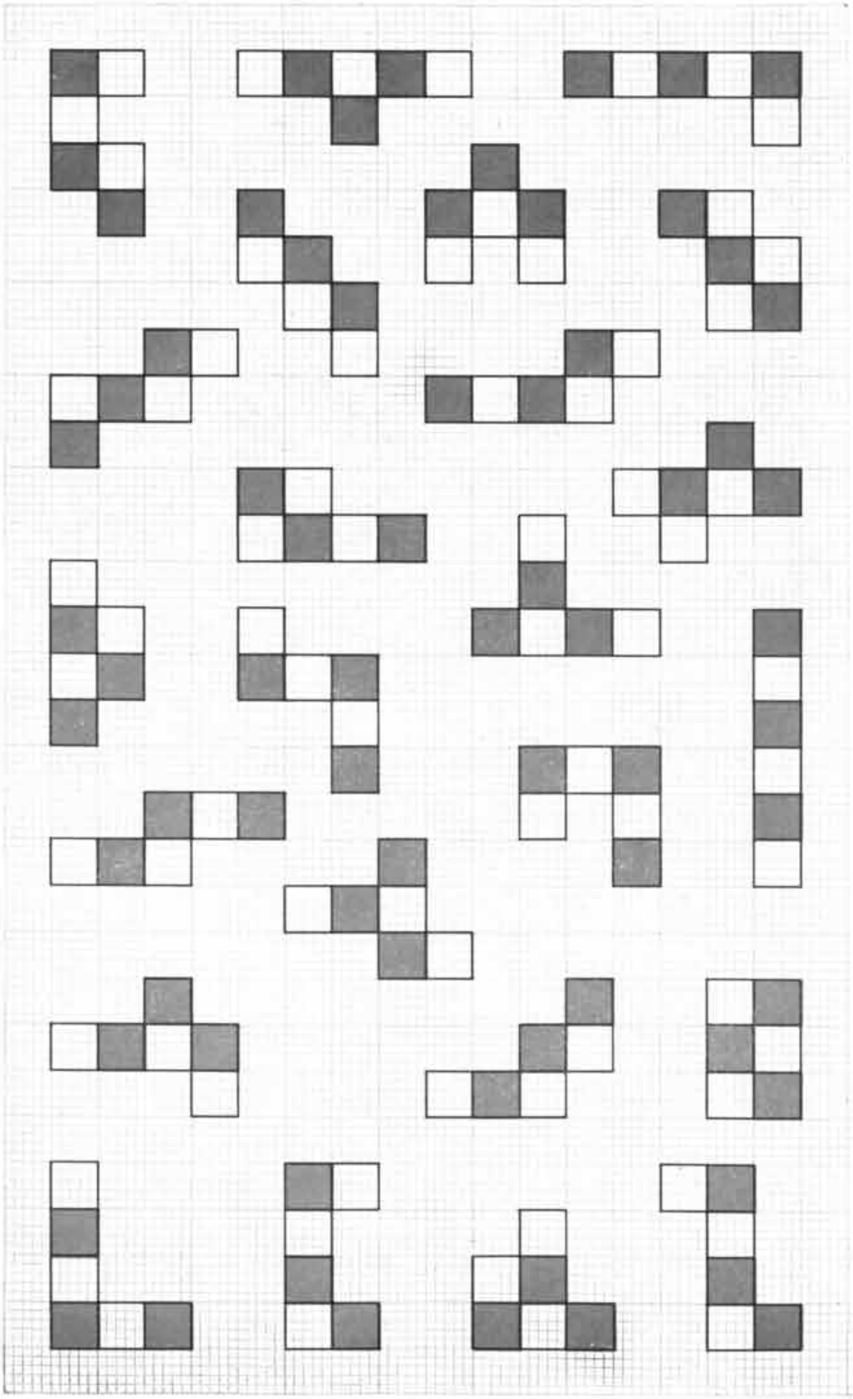
Western Electric

MANUFACTURING AND SUPPLY BELL SYSTEM **UNIT OF THE BELL SYSTEM**

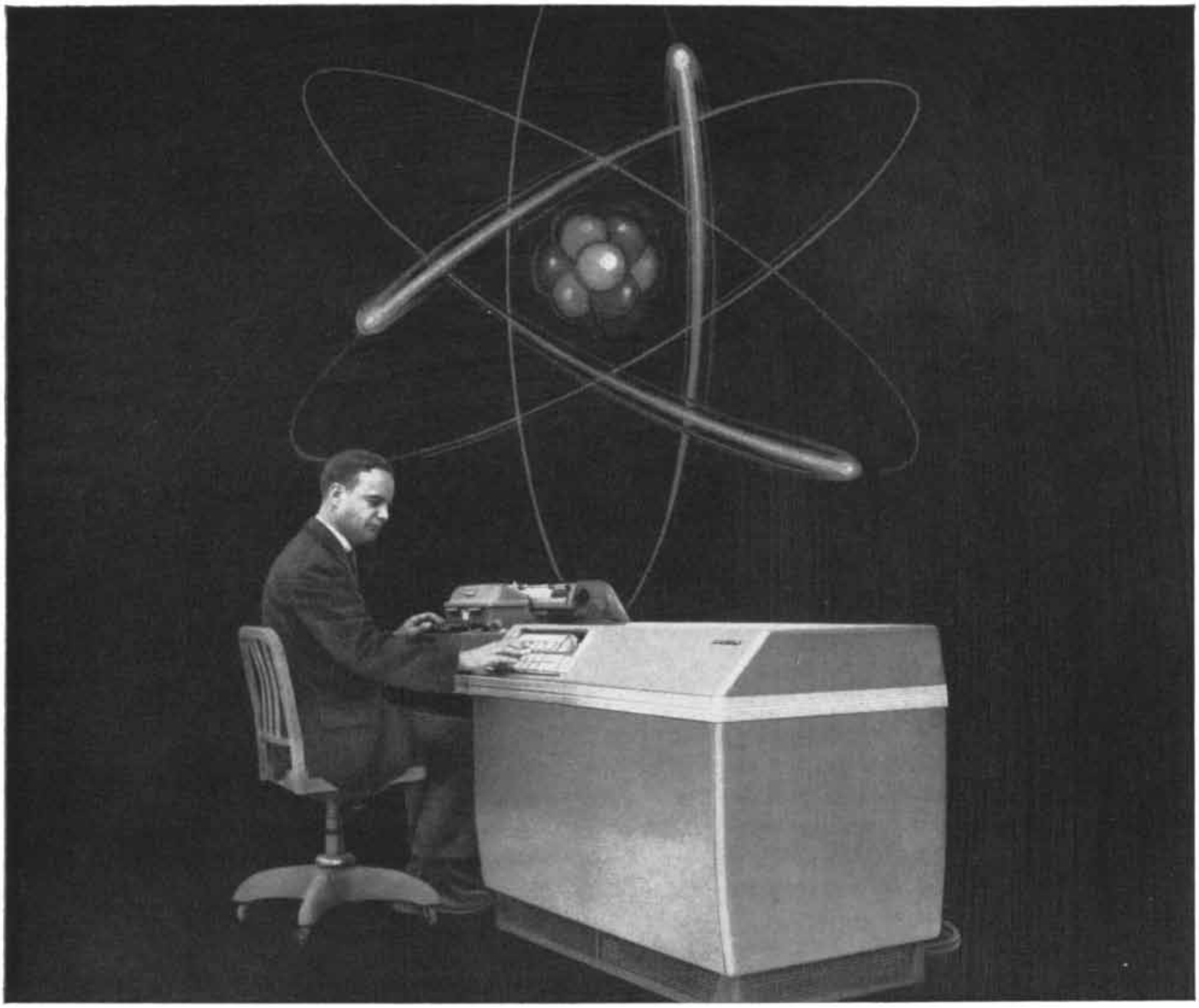
it follows that each boat has gone three times as far as when they first met and have traveled a combined distance of one river-width. Since the white boat had traveled 720 yards when the first meeting occurred, its total distance at the time of the second meeting must be 3 × 720, or 2,160, yards. The bottom illustration shows clearly that this distance is 400 yards more than the river's width, so we subtract 400 from 2,160 to obtain 1,760 yards, or one mile, as the width of the river. The time the boats remained at their landings does not enter into the problem.

3.

Line AC is one diagonal of the rectangle [*illustration at right at top of page 136*]. The other diagonal is clearly the 10-unit radius of the circle. Since the



The 24 "odd" hexominoes



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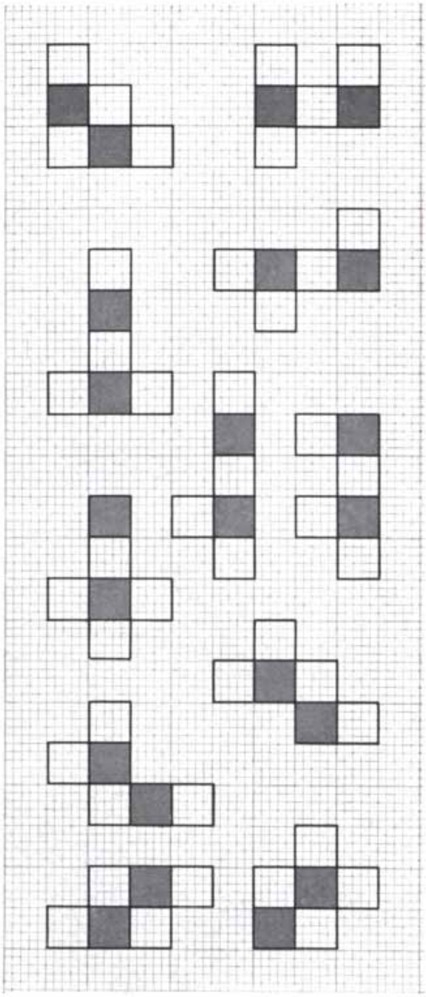

The 11 "even" hexominoes

diagonals are equal, line AC is 10 units long.

4.

On the top floor the electrician shorted five pairs of wires (the shorted pairs are connected by broken lines in the illustration at the top of page 138), leaving one free wire. Then he walked to the basement and identified the lower ends of the shorted pairs by means of his "continuity tester." He labeled the ends as shown, then shorted them in the manner indicated by the dotted lines.

Back on the top floor, he removed all the shorts but left the wires twisted at insulated portions so that the pairs were still identifiable. He then checked for continuity between the free wire (which he knew to be the upper end of F) and some other wire. When he found the other wire, he was able at once to label it E2 and to identify its mate as E1. He next tested for continuity between E1 and another end which, when found,

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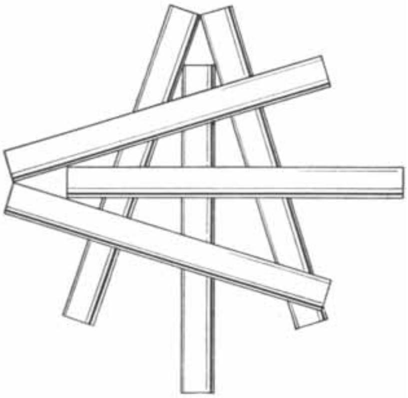
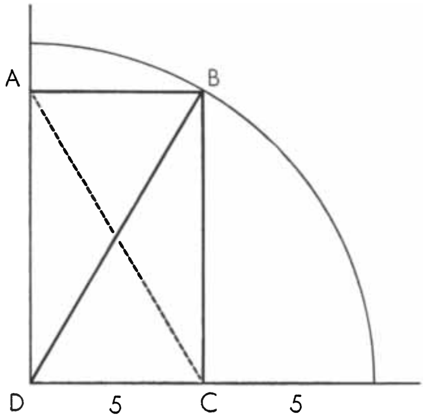




Answers to Puzzle 1 (left) *and Puzzle 3* (right) *in last month's department*

could be marked D2 and its mate D1. Continuing in this fashion, the remaining ends were easily identified. The procedure obviously works for any odd number of wires.

5.

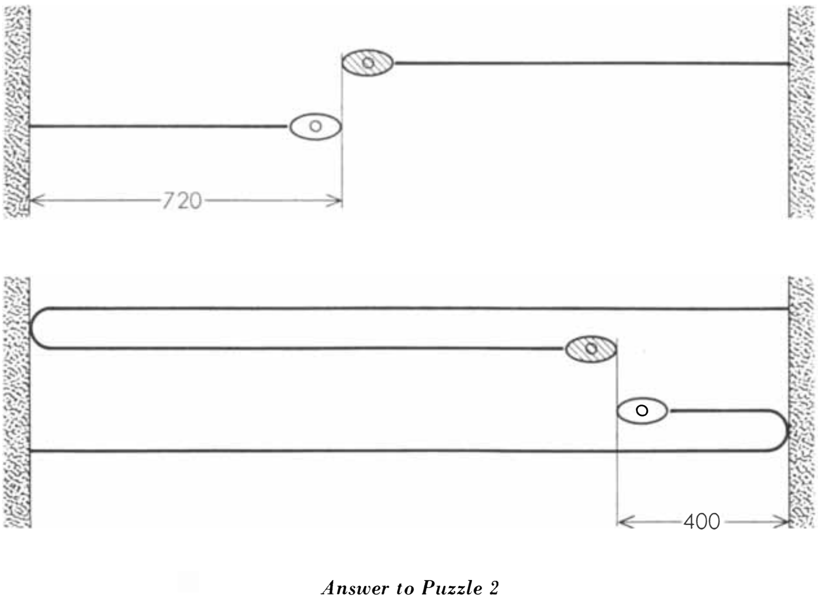
A continuous line that enters and leaves one of the rectangular spaces must of necessity cross two line segments. Since the spaces labeled A, B and C in the illustration at the bottom of page 138 are each surrounded by an odd number of segments, it follows that an end of a line must be inside each if all segments of the network are crossed. But a continuous line has only two ends, so the puzzle is insoluble on a plane surface. This same reasoning applies if the network is on a sphere or on the side of a torus [*drawing at lower left in illustration*]. However, the network can be drawn on the torus [*drawing at lower right*] so that the hole of the torus is *inside* one of the three spaces A, B and C. When this is done, the puzzle is easily solved.

6.

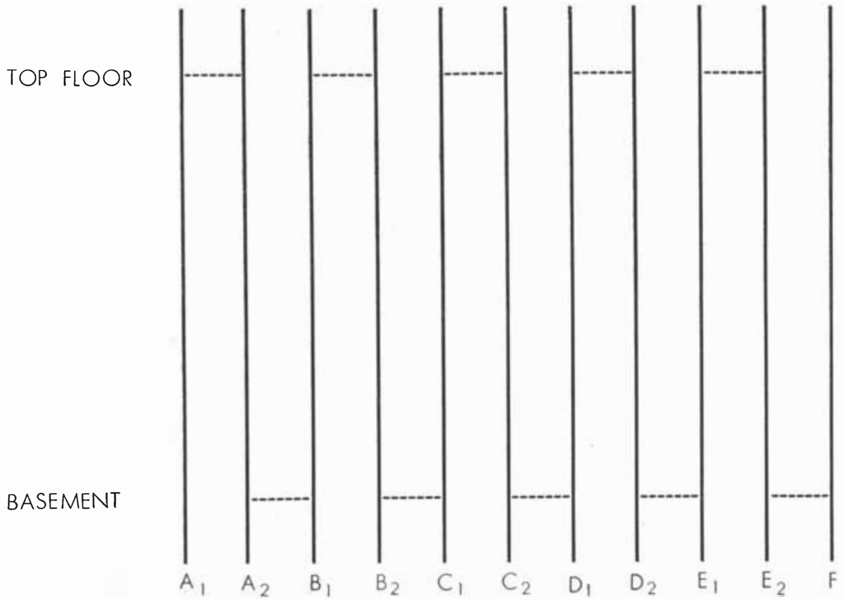
Twelve matches can be used to form a right triangle with sides of three, four and five units, as shown at left in the illustration at the top of page 140. This triangle will have an area of six square units. By altering the position of three matches as shown at right in the illustration, we remove two square units, leaving a polygon with an area of four.

7.

Without resorting to calculus, the problem can be solved as follows. Let R be the radius of the sphere. As the illustration at the bottom of page 140 indicates, the radius of the cylindrical



Answer to Puzzle 2



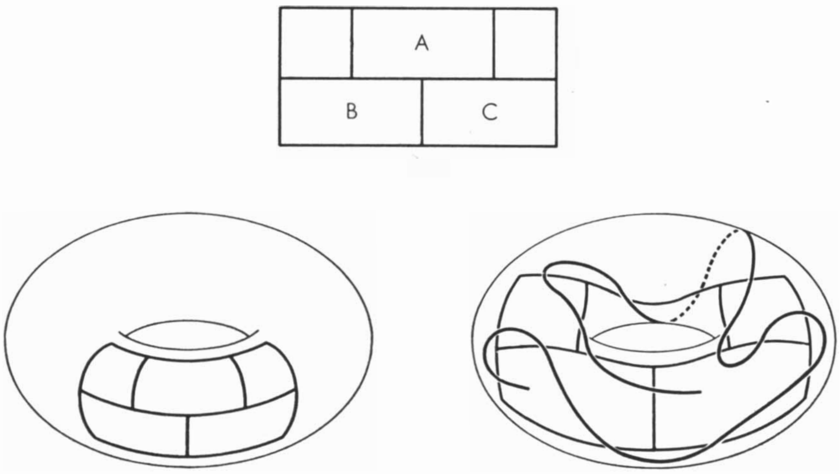
Answer to Puzzle 4

hole will then be the square root of R^2-9, and the altitude of the spherical caps at each end of the cylinder will be $R-3$. To determine the residue after the cylinder and caps have been removed, we add the volume of the cylinder, $6\pi(R^2-9)$, to twice the volume of one spherical cap, and subtract the total from the volume of the sphere, $4/3\pi R^3$. The volume of the cap is obtained by the following formula, in which A stands for its altitude and r for its radius: $1/6\pi A(3r^2 + A^2)$.

When this computation is made, all terms obligingly cancel out except 36π—the volume of the residue in cubic inches. In other words, the residue is constant regardless of the hole's diameter or the size of the sphere! This residue is equal to the volume of a sphere with a diameter of six inches. This is to be expected, since such a sphere may be considered the residue left by a hole with a zero-inch radius.

8.

At any given instant the four bugs form the corners of a square which shrinks and rotates as the bugs move closer together. The path of each pursuer will therefore at all times be perpendicular to the path of the pursued. This tells us that as A, for example, approaches B, there is no component in B's motion which carries B toward or away from A. Consequently A will capture B in the same time that it would



Answer to Puzzle 5

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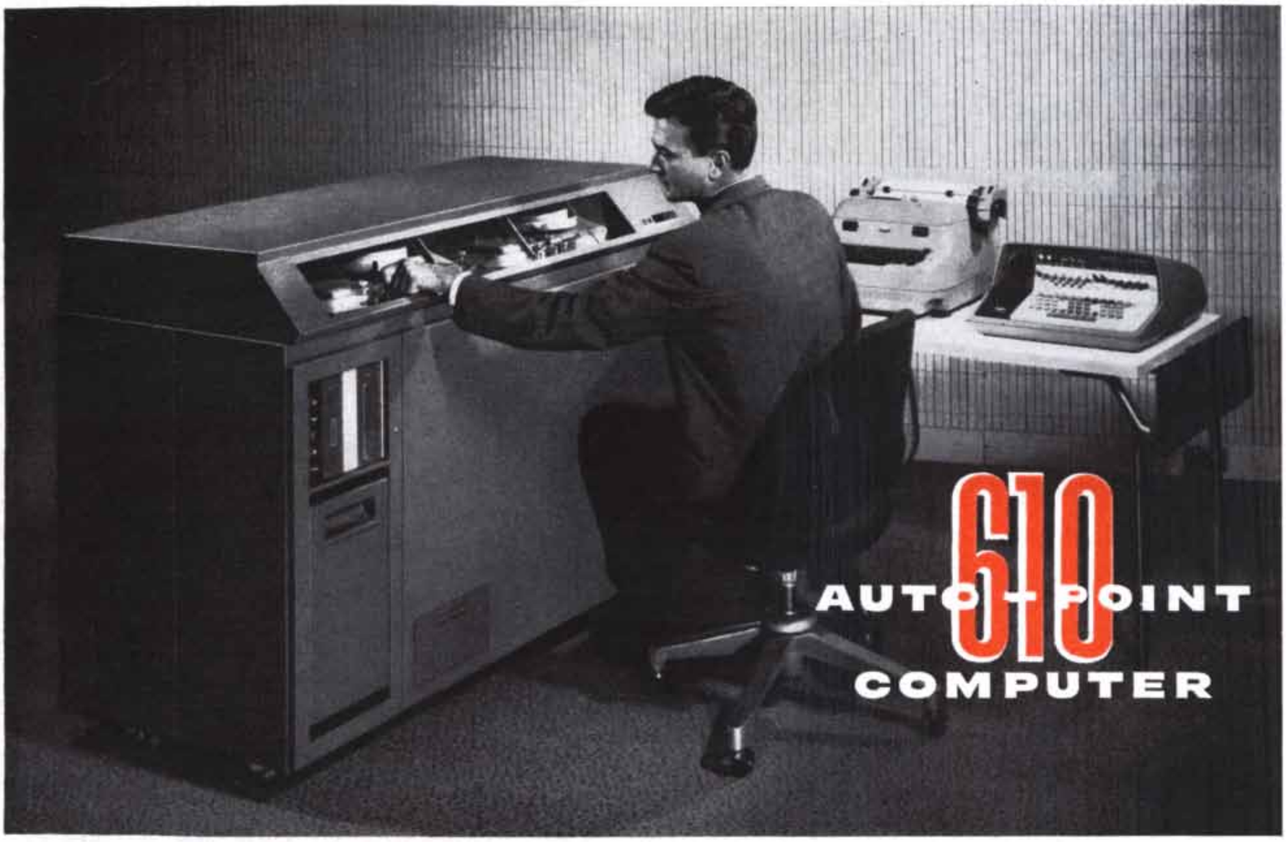

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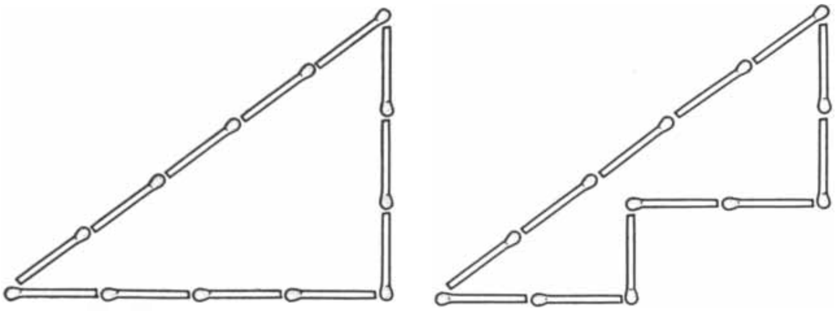


Answer to Puzzle 6

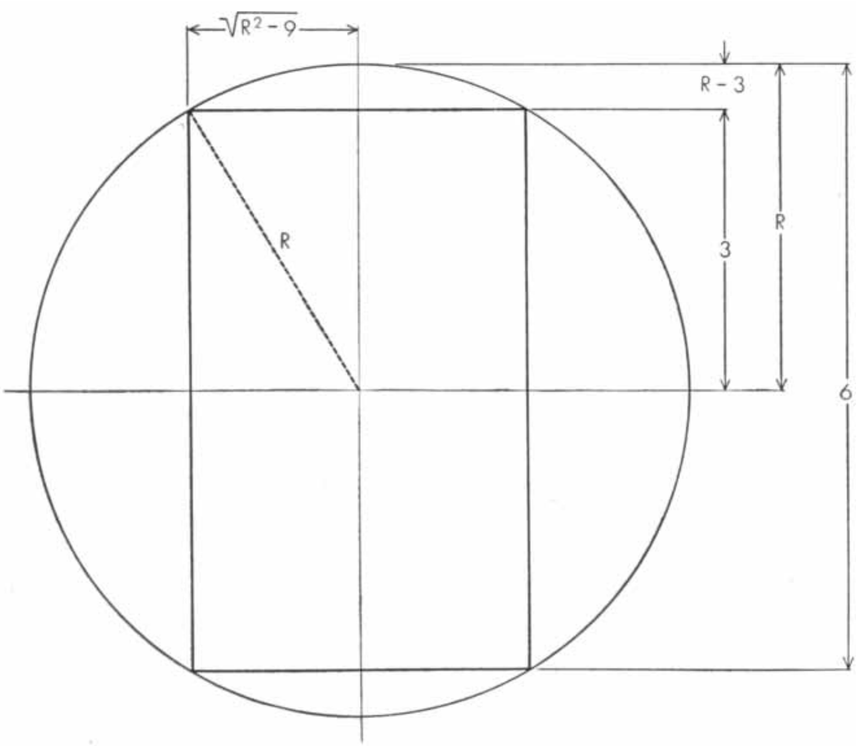
take if B had remained stationary. The length of each spiral path will be the same as the side of the square: 10 inches.

9.

When Jones began to work on the professor's problem he knew that each of the four families had a different number of children, and that the total number was less than 18. He further knew that the product of the four numbers gave the professor's house number. Therefore his obvious first step was to factor the house number into four different numbers which together would total less than 18. If there had been only one way to do this, he would have immediately solved the problem. Since he could not solve it without further information, we conclude that there must have been more than one way of factoring the house number.

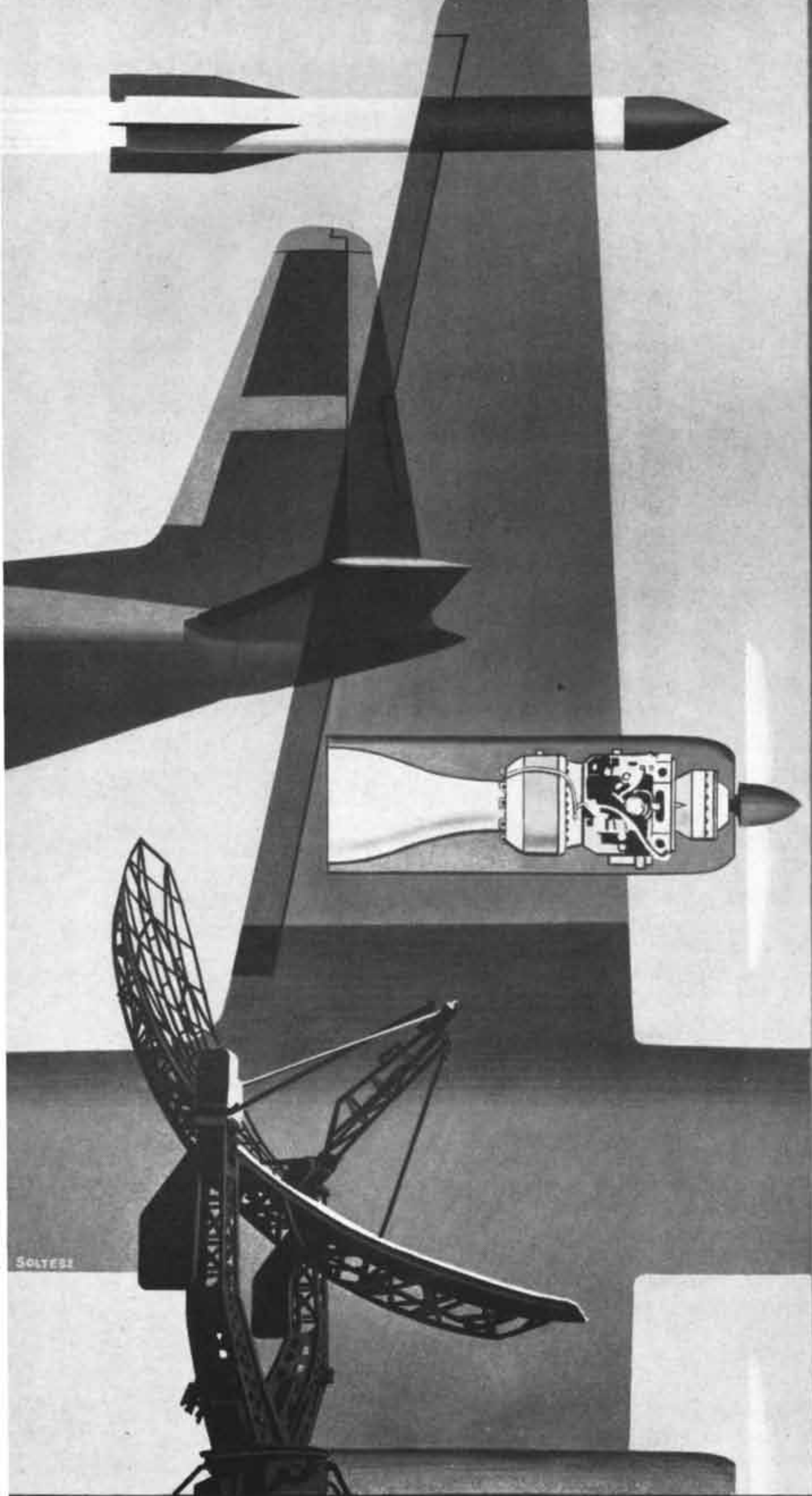
Our next step is to write down all possible combinations of four different numbers which total less than 18, and obtain the products of each group. We find that there are many cases where more than one combination gives the same product. How do we decide which product is the house number?

The clue lies in the fact that Jones asked if there were more than one child in the smallest family. This question is meaningful only if the house number is 120, which can be factored as $1 \times 3 \times 5 \times 8$, $1 \times 4 \times 5 \times 6$, or $2 \times 3 \times 4 \times 5$. Had Smith answered "No," the problem would remain unsolved. Since Jones did solve it, we know the answer was "Yes." The families therefore contained 2, 3, 4 and 5 children.



Answer to Puzzle 7

Avco today



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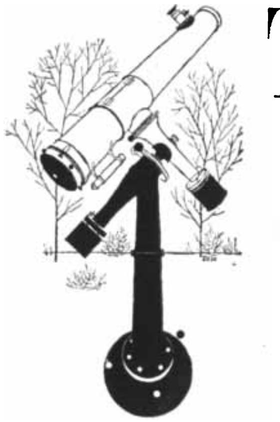


THE AMATEUR SCIENTIST

The strange story of Robert Stroud, who studied birds while in solitary confinement

Conducted by C. L. Stong

One summer day in 1920 Robert F. Stroud found a nest of fledgling sparrows which had fallen from a tree. One bird had suffered a broken leg; Stroud nursed it back to health, thus beginning a distinguished career in the study of bird pathology. In the following 20 years he learned more about the diseases of birds than any amateur investigator before or since. His work attracted the interest of bird lovers and ornithologists throughout the world. Suddenly, in 1942, Stroud's studies were terminated. Today, alone and in ill health, he sits in a room on Alcatraz Island.

One friend has made a point of keeping in touch with Stroud. He is Thomas E. Gaddis of Los Angeles. "Robert Stroud," writes Gaddis, "resists classification. He can properly be called an amateur, because he has never accepted payment for his scientific work. But in Stroud's world our standards and values scarcely exist. He is a prisoner.

"His incarceration spans the 20th century. In 1909 he received a sentence of 12 years for manslaughter (he had killed a man in a fight). When he entered jail, Theodore Roosevelt was President; Admiral Peary had yet to reach the North Pole; plans for the ill-fated *Titanic* had not even been drawn. Since before the U. S. entered World War I, Stroud has been isolated from other prisoners. He has lived in solitary confinement longer than any other prisoner in the annals of the Federal prison system.

"When Stroud first went to prison he was a 19-year-old youth in Alaska. He had a third-grade education. Today he is a tall, thin, bald man with intense blue eyes. He wears metal-rimmed glasses under an old green eyeshade held together with adhesive tape. He is rational and articulate, though he has not broken bread with another human being since 1917. His meals are brought to him on a tray.

"Once a week he is taken down the hall by two guards to have a shower bath. He never gets a breath of fresh air under the open sky; his only exercise is what he gets by pacing his room, which has a handsome view of San Francisco harbor. When no fog shrouds 'the Rock,' he can watch passing ships through his barred window. When the wind is right, he can hear the sounds of city traffic. (He once wrote: 'I know as much about driving a car, or modern traffic regulations, as a Berkshire hog knows about the quantum theory.')

"From his rocky cage Stroud can also see the wheeling gulls and hunting pelicans of the Pacific Coast. But they are far out of reach, and only serve to remind him of the past. For Stroud once lived in a world of birds.

"In the spring of 1920 a gallows was made ready for Stroud in the yard of the Federal penitentiary in Leavenworth, Kan. He was scheduled to be hanged for killing a guard in an altercation before 1,100 prisoners. After four years and three trials, Stroud had been sentenced to death. President Wilson commuted the sentence. Stroud was then placed in solitary confinement for life.

"Such isolation usually turns an uneducated prisoner into a human vegetable. When Stroud first entered prison, he could scarcely read or write. During the next 7 years, before he was separated from other prisoners, he had achieved remarkably high grades in correspondence courses. He had taken instruction in mathematics, astronomy and structural engineering without prerequisite training. He had become an avid reader. In his isolation cell Stroud now taught himself to draw and paint, working under a lone 25-watt bulb. Then came the incident in 1920 which changed his life.

"One day, while he was taking his allotted hour of exercise in a small yard of the prison, a violent storm came up. A branch was torn from a tree beyond the wall and blown into the yard. Under the branch Stroud found a broken nest and three drenched young sparrows. Gathering the fledglings into his handkerchief, he took them inside and warmed them in an improvised incubator—his first piece of scientific apparatus. It consisted of a sock which was hung close to the 25-watt bulb.

"Two of the birds were soon hopping about, but the third could use only one claw. Examination disclosed that it had suffered a broken leg. Stroud set the break and secured it with a splint made from a match and bit of thread. All four of the principals profited by the experience. Although he was confined within a space measuring nine by twelve feet, Stroud had discovered a vast new realm.

"His guards now permitted him to have a male and female canary. Working inside his own cage with a piece of glass and a razor blade, Stroud made a large birdcage out of wooden crates. He was allowed to keep the offspring of his birds; soon his isolated cell was a teeming aviary.

"Stroud quickly discovered that keeping birds on the resources available to a prisoner in solitary confinement invited just about every problem in the book, and some that were not to be found in books. When his birds developed rickets, he learned about vitamins. Friendly guards gave him birdseed, bits of lettuce, bottles, chemicals and hospital pans. He obtained a book on birds, old texts on zoology and bacteriology, and government bulletins. He acquired a magnifying glass. He cultured microorganisms. When one of his birds died, he dissected it with his fingernails, studied its anatomy, and made orderly observations in a notebook.

"During the early 1920s many of Stroud's birds died of avian septicemia, a highly contagious disease. Stroud got no help from his books; they stated that the disease was invariably fatal. After a long series of experiments, he discovered that the tolerance of sick birds for oxygen-liberating compounds was greater than that of mammals. He also learned that chemicals of the citrocarbonate type would restore the alkaline balance lost in avian septicemia. By means of these observations he developed a treatment for the disease. Avian septicemia is often accompanied by skin lesions; these he learned to treat by the external application of potassium permanganate. Stroud was soon working his way through the problem of 'secondary invaders'—other diseases which descend upon a bird weakened by the first illness.

"Stroud was deeply affected by his long surveillance of dying birds. In a book which he published some years later he wrote: 'The lives of literally thousands of birds, the heartbreaks of hundreds of blasted hopes have gone into these pages. . . . For every truth I have blundered through a hundred errors. I have killed birds when it was almost as hard as killing one's children. . . . I have dedicated my book to the proposition that fewer birds shall suffer because their diseases are not understood.'

"Prison officials were impressed by Stroud's earnestness; he was granted privileges and allowed to have more visitors. As his knowledge increased, he began to share it with others by publishing articles in bird journals. He studied English composition. He wangled permission to use a battered typewriter, and taught himself the touch system. His mail privileges were extended. His correspondence multiplied. He gave free advice on how to care for sick birds and how to feed and breed healthy ones.

"Stroud found that all bird infections of the hemorrhagic septicemia group could be controlled by the same methods that were known to be effective in avian diphtheria; he discovered and described a typhoid-like disease of canaries; he demonstrated that apoplectiform septicemia, which sickens poultry, was also a disease of canaries, and that the source of infection lay in egg material; he suggested that psittacosis was a pox-virus infection in modified form; he isolated and identified the organisms associated with three forms of pox-virus disease, demonstrating that most of the fatalities due to the disease were the result of secondary invasion.

"He embarked upon a study of fowl paralysis that was to last for years, and he set up experiments proving that the disease is developed and transmitted by green-plant food. In these experiments he described his methods and invited others to verify his results. His articles were now appearing regularly in bird journals.

"Inevitably Stroud thought of freedom. He wanted to increase the scope of his experiments. He yearned for a microscope, and for more room. He knew he had turned President Wilson's clemency to good advantage. In the years since his life had been spared, his behavior had been exemplary. He wrote friends that he hoped he could start his life again outside prison.

"Then, in 1931, Stroud was ordered to dispose of his birds within 60 days. This was the result of a regulation of the newly formed Federal Bureau of Prisons. Stroud appealed for outside help, enlisting the aid of a bird lover named Della Jones. The case received considerable publicity. Ultimately the Bureau of Prisons allowed Stroud to keep his birds. Moreover, he was provided with an extra cell to house them. He was given new laboratory equipment, multiple electric outlets, dissect-

Stroud made a splint for the broken leg of a sparrow with a match and some thread

He made cages for his birds out of old wooden boxes

ing instruments and, most important of all, a pair of spectacles to correct his poor vision. He was promised a microscope. He was assured of serious consideration for a parole in 1937.

"Stroud's hopes were never fulfilled. Subsequently his freedom of correspondence was restricted. He was no longer allowed to correspond with his energetic friend Della Jones. In 1937 his application for parole was denied.

"Stroud still had many friends. A prison official who had resigned arranged to have Wesleyan University give him an old Spencer microscope. The gift was one of the high points of his life. In a letter of thanks to the University Stroud wrote: 'I once read a newspaper account of a man, blind since birth, whose sight had been suddenly restored. I wondered how this man must have felt as he gazed for the first time upon the world in which he lived, a mystery shrouded in darkness. I know now.'

"Stroud focused his new eye on feathers, microorganisms, blood, gland and bone. His working knowledge of bacteriology soon flowered into practical techniques for making smears and

mounting specimens. He grew adept in the use of Gram stains. He made an intensive study of the blood of birds. He drew 26 illustrations of bird blood-cells, described their cytological detail and later published his drawings in a treatise.

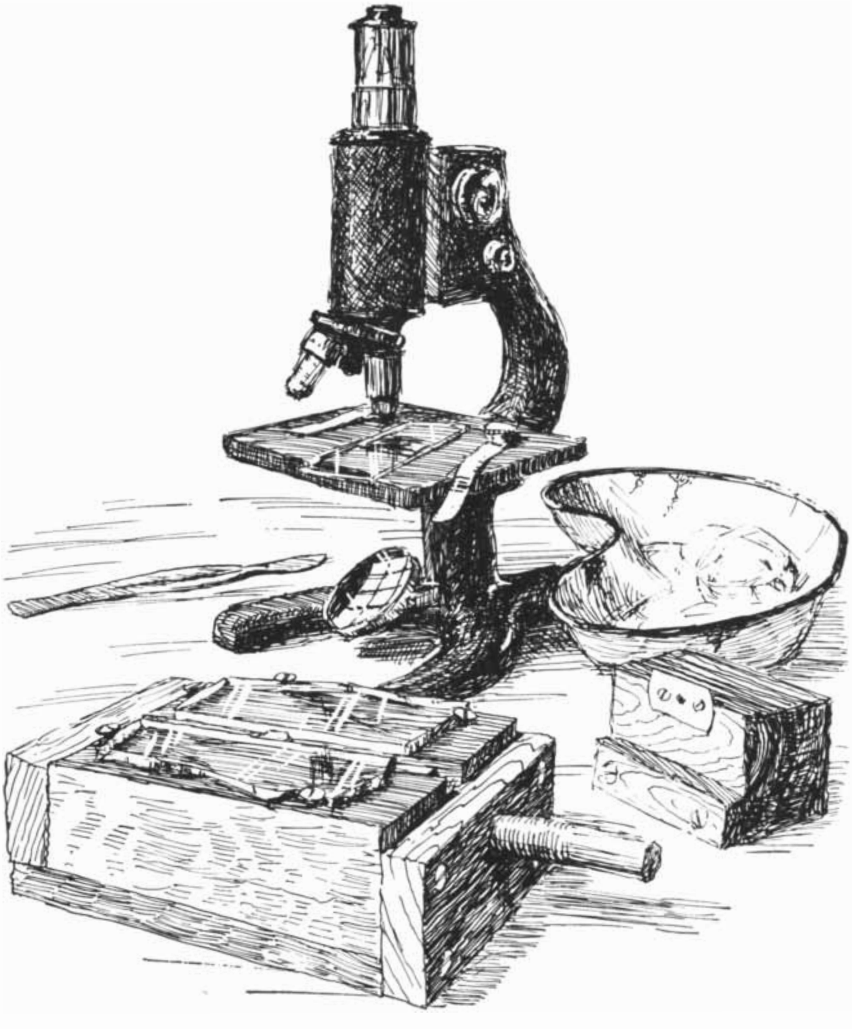
"One day Stroud was given some old slides of tissue sections that had been properly cut and mounted. He plunged into an excited study of histology. He tried again and again to make slides of his own, but was stumped by the difficulty of making tissue sections thin enough to see through. He resolved to build a microtome to cut the necessary slices.

"After two years he succeeded. Writing to a lifelong friend in 1939, Stroud described what is probably the most impressive 'do-it-yourself' feat ever achieved by a prisoner:

" 'I type this letter,' he wrote, 'with sore fingers, but the microtome is finished. For material I had a few pieces of hard wood, some glass, a piece of half-inch rod with threads on it, a tin can, scraps of sheet copper, black enamel and wood screws. I built a machine that cuts down to two microns. . . .

" 'The big problem was to get smooth, uniform motion. I accomplished that by binding all moving and bearing surfaces with tin and copper and polishing them. The screw presses a thin copper wedge under a tin-covered block that is forced up between the glass guides upon which the razor blade, held in a plain oak block, slides and does the cutting. The tissue is embedded in wax and fastened to the top of the block that comes up between the glass surfaces. Since two microns are equal to 1/12,000th of an inch, you can see that any lost motion would upset the whole operation. An irregularity of 1/1,000th of an inch would give sections you could not see through.'

"Stroud plunged deeper into his work. He also struggled against isolation. To the annoyance of prison officials, he managed on several occasions to get his story into the newspapers and on the



He made a microtome which could cut slices two microns thick

radio. In the fall of 1940 his health, which had been declining for several years, fell to a new low. He almost died of pneumonia. But the articles and letters he wrote during this period showed that his mind retained its vigor.

"In 1938, when he was raising pure white Yorkshire canaries, Stroud experimentally fed them anthraquinone dyes. This resulted in lavender and pink canaries, but, more important, it also proved to be an effective treatment for aspergillosis, a fungus disease of birds.

"Later Stroud followed with intense interest the development of sulfanilamide, also a dye, as a therapeutic agent. He concentrated his full energy on anthraquinone, hoping to establish similar properties for this drug. His target was the tubercle bacillus. He lacked facilities for the work, but his efforts attracted the interest of a bacteriologist at the University of Iowa, who visited him in his cell.

" 'He was doing an admirable piece of work under restricted conditions,' the bacteriologist reported. He agreed to carry Stroud's investigation forward.

"Stroud now began work on a book, illustrated with his own drawings, of everything he knew about the care, treatment and diseases of cage birds. Into it went not only the facts he had learned by experiment, but also related observations which come naturally to men who live in cages: Under the title, 'Cages,' he wrote: 'I am qualified to speak for but one group of birds on this subject, the small seedeaters. I want to go on record against that very popular and very stupid abomination, the round canary cage. That a bird is able to live in one of these contraptions says much for his adaptability. . . . Birds like corners for the same reasons you like them: they give a sense of protection. This may be a throwback to the time when both of us crawled out of the sea and hid under a rock, but it is so very real that much of humanity would go mad if compelled to live in round rooms.'

"By 1941 prison officials had grown less tolerant of Stroud's extraordinary activities. It was no longer easy for him to get what he needed for his work. When he was unable to obtain an occasional piece of ice, Stroud wrote the warden of his prison:

" 'As you know, for the last five years I have devoted time to the study of avian pathology and have cut thousands of sections from canary tissue. I am sure that some of my pathological drawings will perform a service long after we are both dead. But under the best conditions the work is not easy. It is so difficult that they do not attempt it in the hospital but send all such work to the Hygienic Laboratory in Washington.

" 'One great difficulty is the fact that the cutting can only be done at the correct temperature. On the outside it is done in air-conditioned rooms where the temperature is thermostatically controlled. I overcame this difficulty by putting my microtome in the icebox until the wax is chilled, and then making the cuts during the few moments when it is just right. But to do this I have to have ice. I have had an order for ice, first issued by Warden White. In the last few years I have been able to get it simply by explaining the need to the guards who understood my work and were sympathetic. Under a change in detail here these conditions no longer exist.'

"The appeal did not succeed. In another letter in which Stroud asked for permission to continue receiving a few simple chemicals, he wrote:

" 'You [the warden] have always been extremely kind and considerate in granting my requests for reagents, though I have little doubt that at times my desires have seemed to you insatiable and beyond reason. But this has only been because the problems involved in the study of bird diseases are no less complex than those in human diseases and of a nature to tax human ingenuity to the limit, even under the best of circumstances. I have felt you realized this and that it was a prompting motive behind your many kindnesses. In appreciation I have been meticulous and diligent in applying these reagents to the sole purpose for which they were granted me. Since these items were not of an objectionable nature, the presumption is created that maybe my own conduct has been in some manner objectionable. If this is the case, I would like to know it and correct the matter.'

" 'The new order,' replied the warden, 'in no way reflects against your conduct.'

"But subsequently, when a congressman appealed to the Bureau of Prisons in Stroud's behalf, Director James V. Bennett replied, '. . . The story of a man like Stroud being interested in birds is, of course, an appealing one, but we are dealing with a very difficult individual who has been a constant source of trouble and agitation since he has been in our institutions, involving incidentally a very considerable expense to the Government. Under the circumstances, I am convinced that it would be decidedly inadvisable to permit Stroud to engage in any such project.' The project was a proposed revision of Stroud's book.

"The effect of such restrictions was

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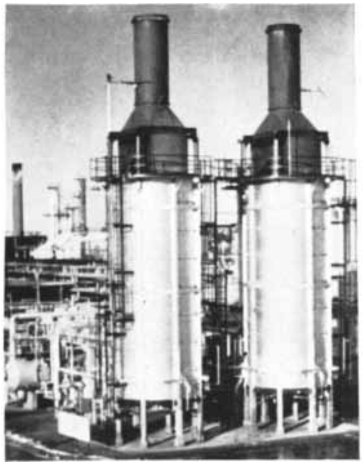

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reflected in Stroud's health and disposition. After he had had a critical bout with pneumonia, an old kidney disease returned. Under these pressures he tried again to bring his situation to the attention of the outside world. He placed copies of a long and bitter letter addressed to his brother in the hands of three prisoners due for release. Two of the copies were intercepted.

"In December of 1942 Stroud was transferred from Leavenworth to Alcatraz. Behind him he left perhaps the strangest collection of objects ever found in a prison cell: half a ton of laboratory, office and bird equipment, including 44 boxes of microscope slides. He also left 22 live birds.

"In Alcatraz Stroud was continued in solitary confinement. Although he was without birds or equipment, he was allowed to complete his book. Today *Stroud's Digest on the Diseases of Birds* is a well-thumbed volume in public libraries and on the shelves of bird breeders.

"Stroud now began an intensive study of penology and law. Ultimately he wrote a 100,000-word analytical history of the Federal penal system from 1790 to 1930. It was confiscated by the Bureau of Prisons. Stroud petitioned the Federal courts for its release, but without success.

"In 1953 Frank Dittrich, who had purchased the copyright of *Stroud's Digest*, requested the Bureau of Prisons to permit Stroud to work on a new edition. This permission was denied.

"My full-length biography of Stroud, *Birdman of Alcatraz*, was published in 1955 by Random House. It has been reprinted in England, West Germany, France and Japan, received wide notice in the press throughout the world and is soon to appear in the U. S. and England in a paper-backed edition. Stroud has never been allowed to read it.

"Article VIII of the Bill of Rights states: '. . . nor (shall) cruel and unusual punishments be inflicted.' To keep any man in isolation from his fellows for more than four decades in this nation of presumed enlightenment would seem to constitute punishment as unusual as it is cruel.

"The Federal Bureau of Prisons was invited this past October to explain its handling of Stroud's case. In response an official of the Bureau stated that he neither could nor would release any facts concerning the prisoner. 'In the opinion of the Bureau,' he said, 'Stroud belongs where he is and he will stay where he is unless his sentence is commuted by the President.' "

BOOKS

A stimulating new discussion of the foundations of probability

by Ernest Nagel

PROBABILITY AND SCIENTIFIC INFERENCE, by G. Spencer Brown. Longmans, Green and Company (18 shillings).

The theory of probability is a flourishing branch of pure mathematics. It is also an indispensable instrument of modern scientific inquiry. Nevertheless, despite the extensive development of probabilistic notions during the past three centuries, probability continues to be a subject for vigorous controversy. This book, by a research lecturer at Christ Church, Oxford, is a stimulatingly iconoclastic contribution to the debate.

Why, and at what points, are the foundations of probability still unsettled? A wit once remarked that mathematicians accept the theory of probability in the belief that it is firmly supported by physics, and that physicists use the theory with confidence because they assume it to be rigorously established by mathematics. This estimate of the situation is no longer accurate, if it ever was, but it suggests an important point. Probability as a purely mathematical discipline is not in fact a controversial matter, for in this sense probability theory consists simply in the logical deduction of consequences from stated axioms or postulates. There are, to be sure, different axiomatic foundations for the theory, and these differences frequently reflect differing intended uses and interpretations for an essentially abstract calculus. However, no one seriously doubts the validity of most of the proofs mathematicians have devised for the characteristic theorems in the subject. One such theorem is that the probability that two events both occur is never greater than the probability that just one of the events occurs. This theorem follows rigorously from axioms normally adopted for the theory. It is true that proofs sometimes proposed for a theorem may be erroneous; but no radical issues are normally involved in identifying and eliminating such error. In short, probability theory as a branch of pure mathematics can indeed be accepted without examining the grounds that physicists (or other empirical scientists) may invoke in judging the soundness of the axioms or the theorems.

The really controversial issues in the continuing debate on probability are of two sorts, one more general than the other. The more general questions relate to constructing an adequate definition for the notion of probability, and to finding useful interpretations for the basic terms of the abstract probability calculus. The more specific problems, not unrelated to the broader ones, are concerned with fixing the range of legitimate application of the calculus, and with determining the conditions for the valid use of its theorems in concrete contexts of inquiry. Three major types of interpretation for the calculus have been proposed. One interpretation (usually called the "subjective" view) takes probability to be the measure of the intensity with which one ought to hold a belief in the occurrence of some event, relative to the available evidence for that belief. A second interpretation (sometimes labeled the "logical" conception) understands by probability an objective logical relation between the premises and conclusion of a given argument, where the premises may imply the conclusion only partially and only to a certain degree. According to a third view (commonly known as the "frequency" notion), probability is an empirical property of events, and the degree of probability of an event is the relative frequency with which the event occurs "in the long run" in some stated class of events. The merits and deficiencies of the alternate versions of probability remain a moot issue. As a matter of fact, however, most empirical scientists at present, as well as a good fraction of statisticians, adopt the frequency conception when they make concrete applications of probability theory.

G. Spencer Brown's book is addressed primarily to some of the more specific issues centered around probability theory, though it also deals tangentially with many other questions. The book is an acute critique, not of the formal validity of the mathematical theory of probability, but of some of the uses to which the theory is often put—especially, though not exclusively, when probability is construed as a relative frequency. Brown's main contention is that a variety of statistical inferences, drawn in accordance with important theorems in probability theory, are in fact invalid. He calls these inferences invalid because the conditions under which the supporting theorems are theoretically sound are never fully realizable in practice. Brown singles out two such conditions for particular attention: one is the condition that the events to which probability theory may be applied are in some sense "random" or "haphazard" in their occurrence; the other is the condition that, though an event occurs in a random fashion, it nevertheless has a determinate or "true" probability. Brown's discussion from this perspective of the evidence for the reality of extrasensory and other parapsychological phenomena is particularly interesting. He also believes that what he calls the "classical" probability theory (under which label he also includes the relative-frequency conception) has been developed and employed on the basis of dubious "metaphysical" assumptions. But while he offers some hints as to what should replace these assumptions, his book is frankly a job of demolition rather than of reconstruction.

The difficulties to which Brown calls attention all hinge, in one way or another, upon the sound point that the tests for statistical significance prescribed

EDITOR'S NOTE

Each December since 1949 this department has reviewed a considerable number of books about science for younger readers. The custom is continued in this issue, although fewer books have been selected for review. The reviews begin on page 162.

by probability theory are valid only if the data in the samples used as the basis for inference have been obtained in a random manner. For example, suppose we wish to test the efficacy of a new fertilizer by applying it to different parts of a certain wheat field. If the chemical is spread on parts of the field in which wheat ordinarily does well, but withheld from ground in which wheat usually does poorly, our sample crop will not be obtained at random, and our "experiment" will prove nothing. We must therefore distribute the fertilizer at random. A customary method of randomization is through the use of random numbers, somewhat as follows. Divide the field into, say, 20 strips of equal area, and number them consecutively. Let some "chance machine" (for example, a suitably constructed roulette wheel) select at random 10 numbers from the first 20 integers. (Numbers obtained by some such random process have been published as tables of random digits.) If strips corresponding to the selected integers are treated with the fertilizer, while the remaining strips are not, our sample crop would normally be said to have been obtained at random.

A problem nevertheless remains as to whether the device used to select the numbers really is a "chance machine"—whether, that is, the numbers have really been selected at random. It is clear that we must first ask what we mean by "randomness," and it is to this question that much of Brown's discussion is devoted. An event is sometimes said to occur in a random way if we are unable to predict its recurrence. But this notion of randomness is patently "subjective," in the sense that whether an event is judged to be a random one will in general vary from person to person, and will depend on the state of scientific knowledge. A more objective notion of randomness is conveyed by the following idea. Suppose that each one of a set of events is realizable under certain circumstances, but that the events are actually realized in a haphazard way, so that no order is discernible in the way those events recur. Each event in that set of possible events is then said to occur at random.

To illustrate this "objective" sense of randomness, let us try answering the question whether on a given coin heads (H) and tails (T) turn up at random. One might be tempted to reply that this is an easy question, if we can assume that the probabilities of H and T are each 1/2, and also that repeated tosses of the coin are independent of one another (that is, the outcome of one toss does not affect the outcome of another toss). True. But how do we know that these are the probabilities, and that repeated tosses are independent? On the frequency view of probability we must ultimately consult empirical frequencies, so let us flip the coin 100 times. If H turns up 51 times, we are likely to accept the hypothesis that the probability of H is 1/2, despite the small bias favoring H. On the other hand, if H turns up 99 times, we are likely to reject this hypothesis and attribute a definite bias to the coin favoring H.

However, before we decide whether or not H occurs in a random fashion, two important difficulties should be noted. In the first place, we have tossed the coin just 100 times, and the outcome of this set of tosses is obviously not sufficient for concluding how the coin will behave "in the long run." The set of actual tosses is but a sample from the indefinitely large population of potential tosses of the coin. But if we are to assign any statistical significance to the data in the sample, the sample must have been drawn at random. The problem of randomness raises its head again. The problem is made more acute by the reflection that even if the "real" probability of H is 1/2, then provided the tosses are independent there is a small probability that H will turn up 99 times in 100 trials (as an easy calculation shows). Analogously, even if the "real" probability of H is 99/100, there is a small chance that H will turn up 51 times in 100 tosses. It becomes evident that unless some further assumptions are introduced, the evidence yielded by the experiment of tossing the coin 100 times is not decisive for or against any statistical hypothesis. This conclusion holds no matter how large the sample with which we work.

One such assumption that will readily occur to us may postulate the "representative" character of the sample; for example, we may assume that if a sample shows only a very small bias favoring H, then further samples will for the most part exhibit a similar bias, while if a sample shows a marked bias toward H, further samples will in the main also display such a bias. An assumption of this sort is tantamount to the adoption of a rule of procedure which says that probabilities smaller than a predesignated value are to be equated with zero. Thus, if on the hypothesis that the probability of H is 1/2, the probability of getting 99 heads in 100 trials is less than, say, 1/1,000, and if in a given set of 100 tosses H does turn up 99 times, then the rule requires us to reject that hypothesis. Nevertheless, the theoretically justifiable use of this rule presupposes that the 100 tosses constitute a random sample.

But there is a further point. Though a series of tosses may show little or no bias favoring H (that is, the relative frequency of H is approximately the same as that of T), it may exhibit considerable bias favoring various complex events which are combinations of H and T. Suppose, for example, that H and T turn up in the following order: first H followed by T, then two H's followed by two T's, then four H's followed by four T's, then eight H's followed by eight T's, and so on. The series then looks like this: HTHH TTHHHHTTTTHHHHHHHHTTTTT TTT. . . . The relative frequency of each of the "atomic" events H and T is 1/2, so that the series is unbiased with respect to them. But the relative frequencies of the "molecular" events HH, TT, HT, TH are not the same, and in fact the series is strongly biased in favor of the first two. It is indeed unlikely that anyone would regard the series to be random in respect to the occurrence of the atomic events, since there is an obvious pattern in the way H and T appear; and this lack of randomness is reflected by the bias in the series favoring the indicated molecular events. In general, therefore, a series may exhibit many kinds of bias: though it may show no bias favoring its atomic events, it may exhibit a readily discernible bias in favor of various kinds of molecular events. However, unless a series possesses no bias in respect to an indefinitely large class of both its atomic and molecular events, it is not ideally random; and in that case many important theorems in the calculus of probability, extensively used in drawing statistical inferences, cannot be validly employed in connection with the series. For example, the glaringly nonrandom character of the above illustrative series precludes the application to it of the very important Bernoulli theorem. The content of this theorem can be explained as follows. Suppose H and T occur in a very long (strictly speaking, infinite) series in an ideally random manner, and that the theoretical probability of H is 1/2. Break up the series into sets of n consecutive tosses (where n may be 100, or 1,000, or any number we please), and ascertain for each of these sets the relative frequency of H in it. In some of these sets the relative frequency of H will not differ from the theoretical probability of 1/2 by more than, say, 1/20; call such sets "sets of the first kind." In other sets the relative frequency of H will differ from 1/2 by more than 1/20; call such sets "sets of the second kind." It now

In telescope mirrors, the reflecting part is a film of aluminum applied over glass by vacuum distillation. This film takes its shape from the glass which has been ground and polished to a paraboloid that brings light rays to a focus. In the application described here, titanium would replace glass.

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turns out that the relative frequency of sets of the first kind is in general much greater than the relative frequency of sets of the second kind. Moreover—and this is the crucial point—if n is increased (for example, from 100 to 1,000, or from 1,000 to 10,000) the relative frequency of sets of the first kind will become progressively larger; indeed, by increasing the value of n sufficiently, the relative frequency of sets of the first kind can be made as close to 1 as we please. Under the conditions assumed we can therefore predict with high probability that in a random sample of n tosses (where n is sufficiently large) the relative frequency of H will differ from 1/2 by less than 1/20. However, this result does not hold for the above illustrative series (in which one uninterrupted sequence of H's alternates with a similar uninterrupted sequence of T's, and the uninterrupted sequences become longer and longer), for by virtue of its nonrandom character sets of the second kind will far outnumber sets of the first kind. Were we in this example to use Bernoulli's theorem to predict that in, say, 100 tosses, H will turn up with a relative frequency close to 1/2, we would fall into error in an overwhelming proportion of cases.

Now it is the main burden of Brown's critique that the ideal randomness presupposed by the theory of probability is not, and cannot be, fully realized in practice. He therefore concludes that inferences drawn from actual statistical data in accordance with theorems of that calculus—and in particular inferences which postulate some causal factor to account for a bias in the data—are generally suspect. They are suspect because the bias detected in the data may be simply the consequence of some subtle failure in randomizing the experiment generating those data, and may therefore have no further significance.

Brown's point can be made clear by considering the famous example of the tea-tasting lady. The lady claims that she can tell by simply tasting a cup of tea whether milk or tea was poured into the cup first. To test the claim she is given eight cups of tea, four of which are prepared by pouring the milk first (M) and four by pouring the tea first (T); and she is asked to identify the cups by tasting their contents. Now an elementary computation shows that if the lady does not really possess the powers of discrimination she alleges, but is only guessing, then the probability is 1/70 that she will identify the cups correctly in a single trial. This is a small probability, so that if the lady does happen to call all the cups correctly we are likely to be impressed and may be strongly inclined to grant her claim. Suppose, however, that though she is only guessing, her guesses (like those of most people) tend to occur in a certain order. To fix our ideas, assume that the order is MTMTMTMT. On the other hand, in presenting the cups to the lady the experimenter will attempt to offer them in a random order. But the experimenter may himself have the tendency to order the cups in a certain way, even when he thinks he is ordering them in a random manner. Let us exaggerate for purposes of illustration, and assume that in fact he presents the cups in the order MTMTMTMT. Accordingly, the lady will call the cups correctly, whether she has the power of discrimination she claims or is only guessing. It is therefore evident that if we now conclude that the lady does possess her alleged power in order to explain her apparently successful performance, the conclusion follows only because of faulty randomization in the design of the experiment.

The patently nonrandom arrangement of the cups in this example has been introduced for the sake of ready comprehension, but the point of the example does not depend on this. Moreover, while it is the human experimenter who is responsible in this case for the nonrandomness, Brown shows convincingly that even mechanical randomizers (*e.g.*, chance-machines used to select lists of random digits) must inescapably display some form of bias. For as he correctly observes, though the elements of a sample may be selected in random order, in the sense that they exhibit no discernible pattern of arrangement of one kind, it does not follow that they exhibit no pattern of arrangement of some other kind. Indeed, it is self-contradictory to suppose that a class of elements has no order whatsoever, and the conception of an "absolutely haphazard" series of events is logically absurd. In consequence the randomness of a sample is always relative to some specified set of patterns, and given time enough we are bound to discover some determinate order of arrangement or bias in any finite class of events. Brown describes this predicament amusingly: "We have a randomizing machine which produces a series of ones and noughts. We require for experimental purposes a random series of 16 ones and noughts. We start the machine which now gives us a series of 16 noughts. We of course reject this series as unsuitable and suspect the machine of being biased. It is returned to the makers for adjustment. When it comes back we have a very long experiment for which we require a random series of 2,000,000 ones and noughts. We leave the machine running all night, but on checking through the 2,000,000 ones and noughts it produces we are surprised to find not a single run of 16 noughts. Again we suspect it of being biased and send it back. But what is its designer to say to all this? First we send it back because it produces 16 noughts in a row. Very well: he puts in a device to prevent its doing this. We then send it back because it never produces 16 noughts in a row. What is he to do now? First of all we use a specific criterion to reject the series the machine produces, and then we use the absence of this very criterion to reject another series it produces. It seems we are never satisfied."

So no actual sample is absolutely free from bias. Two things nevertheless save scientific inference from invariably falling into gross error as a consequence of the inevitable bias in the selection of samples. One is that the bias produced by inherent structures in the subject matter of inquiry frequently outweighs the bias introduced by any particular randomizing agent. The second is that the self-corrective sampling method of science is in principle nonterminating, and employs increasingly more diverse and sensitive tests for relevant bias. Brown develops these points briefly but vigorously, and argues that science is in general a continuing activity of inquiry and experimentation, not a historical record of what has already happened. As he eventually summarizes his view, scientific knowledge is "prevented from dwindling completely into anecdote only by the attitude which seeks to repeat experiments and confirm results without end."

Little in all of this is really novel, and much of it has been noted by some of the very proponents of the theory of probability (for example, the late Richard von Mises) against whom Brown levels his critique. But he develops his argument with a fresh view, makes some illuminating applications of them and draws from them a number of striking (though not always well-reasoned) conclusions. Of particular value are his comments on the operation of randomizing machines. He makes plain how much tampering must be done to them, and how much "cooking" of their initial products must take place, before practically usable "random" series are obtained. He has taken the trouble to examine some published tables of random digits, and has found various statistical "oddities" in them. For example, when two arbitrarily selected columns of random digits were matched to discover whether the corresponding numbers agreed in being odd or even, the result differed significantly from what was to be expected on the assumption that the columns were constructed by a "pure chance" selection of the digits. Brown believes his findings are difficult to understand on the basis of classical probability analysis. He maintains that classical theory "has always prevented our talking about [such] oddities in terms of chance," largely because of its mistaken "metaphysical assumption" that there is such a thing as "the true probability" for an event's occurrence. His own explanation of such statistical aberrations is that every chance-machine will produce events in proportions differing by as much as we please from any initial estimate of the probabilities of those events. Moreover, he thinks it unreasonable to expect that a given tendency of a mechanical randomizer to produce biased series will remain constant indefinitely, since even if there is no deliberate interference with the machine's operation it is bound to wear out and to suffer a variety of changes with time.

Much of this makes excellent sense, and helps to make intelligible how it is possible for a randomizer to exhibit an impressive bias for a time, only to have this bias gradually diminish or even disappear. On the other hand, it is difficult to find in Brown's discussion convincing reasons for doubting the adequacy of the classical probability theory. His animadversions on that theory appear to boil down to the simple point that when its formulations are taken literally, and since there are in fact no ideally random series and no ideally constant relative frequencies, the theory is useless for scientific practice. But to evaluate a theory in this manner is to take a somewhat myopic view of the function of theory in experimental science. Such criticism would lead to the rejection of most mathematically formulated theories as useless. In fact, most physical theories developed in modern times employ various kinds of "limiting" or "ideal" notions, to which nothing in nature literally corresponds. These theories are nevertheless associated with supplementary rules of interpretation and application, which indicate in what manner those notions are to be used in connection with the gross materials of experience. For example, the theory of mechanics is commonly stated in terms of such concepts as instantaneous velocity or continuously varying density. But it would be absurd to dismiss the theory of mechanics as useless because no measurable velocity is instantaneous and no physical body is mathematically continuous. Now the classical frequency theory of probability is in an analogous position; and the functional significance of its "ideal" notions must similarly be construed in terms of rules of application, such as those implicit in the use of levels of statistical significance and the like. It is not essential that, to be useful, the predictions of a theory correspond precisely to the facts of experience; it is sufficient if, through the mediation of such supplementary rules of interpretation, the correspondence is rough and approximate. It is therefore a mistake to read a mathematized theory (such as the theory of probability) as a literally accurate description of the actual course of events; and it is no less a mistake to reject such a theory because it provides no such description.

Brown nonetheless makes effective use of his adventures with random numbers in his extremely acute comments on some of the statistical data of recent psychic research. These data exhibit statistical patterns which have been interpreted to signify the reality of parapsychological phenomena, such as extrasensory perception and telepathy, but which in important respects are very much like the "oddities" Brown has discovered in tables of random digits. He therefore raises the pointed question: "Why say that when significant biases occur in certain circumstances they are evidence of marvellous telepathy, but when they occur in other circumstances they are just statistical artifacts or mistakes on the part of the operators? It is much simpler to suppose that they are in each case the same thing." And he does not hide his conviction that the departures from "pure chance" expectation exhibited by psychic research data are best explained, for the present at any rate, as consequences of certain inherent limitations in the design of psychic experiments, rather than as the manifestations of hypothetical parapsychological powers. Brown has not established his case beyond all doubt, and certainly the data he makes available in this book on the statistics of random numbers are not sufficient to make completely secure his general views on randomizing machines. His discussion of the statistics of psychic research nonetheless opens up a fresh perspective for evaluating the results so far obtained. In any event his analysis of those data is the only published account with which this reviewer is familiar that

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offers a reasonably plausible explanation for them.

Brown discusses a large variety of other topics, often with insight but not always cogently. He would have written a better book, and certainly a better-organized one, if he had touched on fewer themes and had instead developed his main points more fully. Even so, enough has been said to make it evident that his book is both challenging and important.

Children's Books

ALL ABOUT ELECTRICITY, by Ira M. Freeman. Random House ($1.95). For youngsters beginning to take an interest in electrical and magnetic phenomena, Dr. Freeman's sound, simple book will serve as a helpful steppingstone. He sketches the history of the subject, the discovery of the laws of static electricity, magnetism, electric currents, the invention of electromagnets and electric motors, the principles of the telegraph and telephone, the elements of wireless and electronics. Excellent illustrations.

CHEMISTRY CREATES A NEW WORLD, by Bernard Jaffe. Thomas Y. Crowell Company ($4.50). Dr. Jaffe has written several excellent popularizations of science and a superior textbook of chemistry. We must now credit him with a most readable survey—addressed to adolescents—of the achievements of modern chemistry. Two introductory chapters deal with the nature of chemistry, the historical development of basic concepts and the universal symbols of the science. Jaffe then explains the structure of flame, soap, water, baking powder, ammonia water and other substances and processes to be found in the kitchen. This discussion leads into reports on new medicines, agricultural chemicals, advances in metallurgy, synthetic gasoline, rubber and fibers, and various constructive applications of atomic energy. A fine balance is achieved of exposition, history and biography, to make this an exceptionally attractive book of knowledge.

THE CHEMICAL HISTORY OF A CANDLE, by Michael Faraday. Thomas Y. Crowell Company ($2.75). A reprint of these famous Christmas Lectures which Faraday first delivered to an audience of young people at the Royal Institution in London in 1848. He explains how a candle is made, how it burns, what is involved in the chemistry of combustion. He discusses the source and brightness of the flame, the water produced in the burning process, the hydrogen in the candle, the nature of the surrounding atmosphere which supplies the oxygen. To his incomparable gifts as an experimenter Faraday added a superb capacity for describing and demonstrating physical phenomena. Schooled as assistant to Humphrey Davy—who was himself a brilliant lecturer—Faraday painstakingly drilled himself in the platform art. He was master of his subject; he had a lucid delivery; he delighted in devising ingenious instruments and demonstrations, and he was contagiously enthusiastic. Unquestionably he was the foremost scientific lecturer of his day. The present edition has a graceful biographical introduction by Sir J. Arthur Thomson and a foreword on the Christmas Lectures by E. N. da C. Andrade. The illustrations have been redrawn by Jeanyee Wong: some are clearer; some new ones are added; some old ones eliminated. The result is pictorially satisfactory, but it is a sad fact that the charm of the illustrations found in older editions has vanished.

BUILDING BLOCKS OF THE UNIVERSE, by Isaac Asimov. Abelard-Schuman, Ltd. ($3). Each of the 102 chemical elements—nobelium was just synthesized when the book went to press, and gets a nod—is briefly treated in the latest of Dr. Asimov's science primers for youngsters. He explains how the elements were discovered, their properties, their compounds. Unfortunately, except for a rather pointless pair of periodic tables (one has only numbers; the other, only names), there are no illustrations.

SUN, EARTH, AND MAN, by George P. and Eunice S. Bischof. Harcourt, Brace and Company ($2.75). Around the universe in a rocket. Neither time nor space stay the Bischofs from the swift completion of their self-appointed rounds: the sun and the planets; the origins of the earth; the beginnings of life; prehistoric animals and early man; biological and technological evolution; the physical features of the globe today; how man fights disease, climate, drought, flood and the destroyers of his crops; how men have wasted the earth and how others are trying to conserve its resources; the possibilities of future developments. Total: 25,000 words. This volume may nonetheless suit the literate youngster who wants no more than a taste of scientific information, administered in small doses.

INSECTS ON PARADE, by Clarence J. Hylander. The Macmillan Company ($3.75). Among the members of the

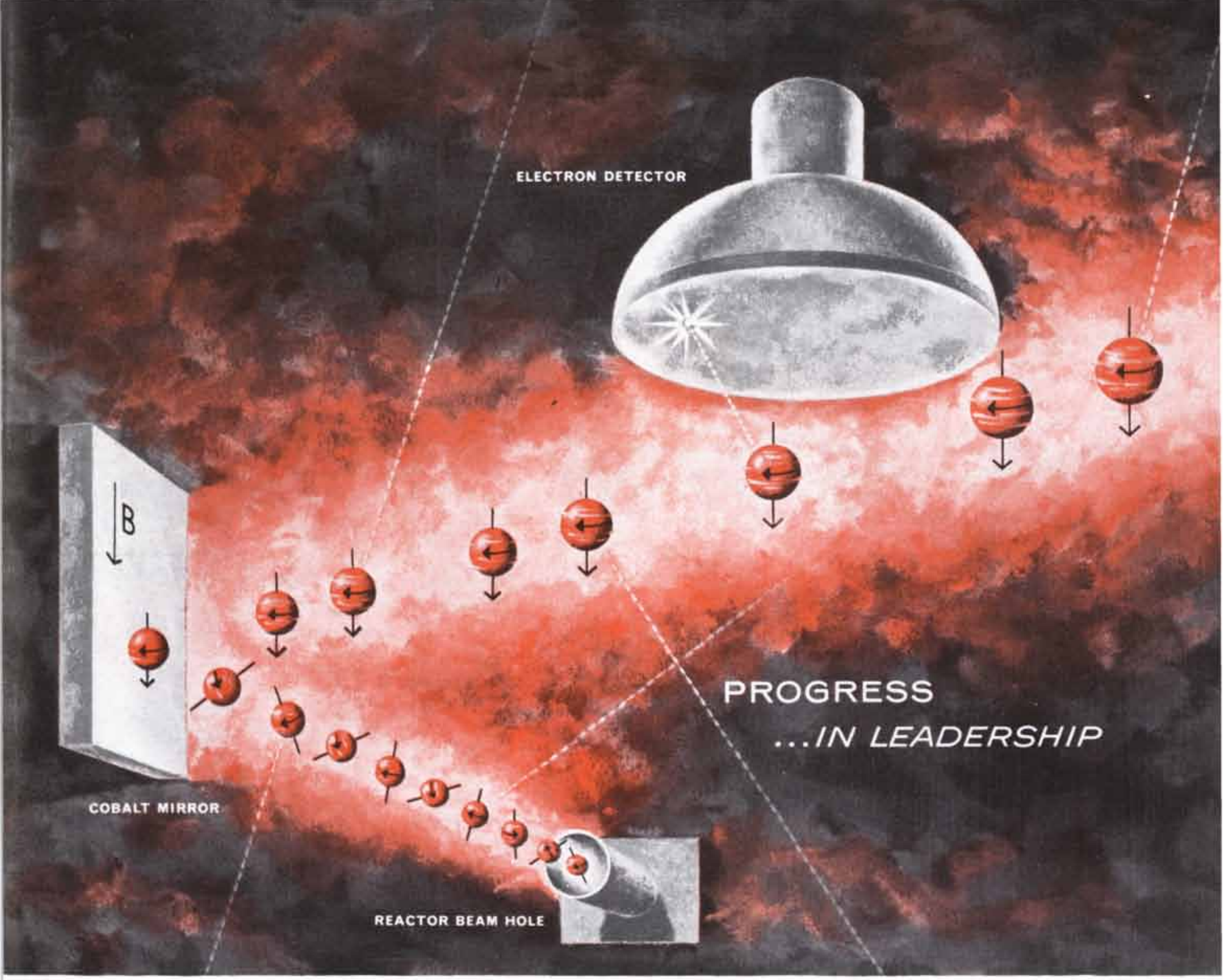
parade whose appearance, habits and peculiarities are recounted in these pages are grasshoppers; walkingsticks; mantids; stink, squash and chinch bugs; click, scarab, stag, snout, diving and whirligig beetles; butterflies; moths; house, blow, fruit and horse flies; wasps; bees; ants, and termites. Plain exposition; sensible line drawings; good photographs.

A HARE ABOUT THE HOUSE, by Cecil S. Webb. Houghton Mifflin Company ($2.75). During his tenure of office as superintendent of the Dublin Zoo, Cecil Webb, an experienced curator-collector of wild animals, adopted into his household a baby Irish hare. This is the story of its domestication, education and happy life in the Webb's home. Horrie—short for Horace—was a member of a breed known for its exceptional timidity in the wild state. Affection, patience and profound understanding did wonders for him—as they do for anybody. He was nursed on milk from a fountain-pen dropper. He slept in a cozy box-bed next to the stove in the kitchen. He would drum on the sides of the box to get attention. He kept himself clean and was easily housebroken. He explored every corner of the house, raced up and down stairs and became skilled in playing tag and other games with his foster parents. He learned to walk like a performing bear, to beg for toast and marmalade, to sleep on a pillow, to answer to his name, to knock on the door when he wanted to go in or out, to feign sleep, to poke at his master as an invitation to play. Early in his life the Webbs provided him with a companion, an orphaned albino rabbit who was christened Squirt. They got along fine. Squirt was particularly devoted to the hare and would help him clean himself; Horace would occasionally condescend to give the rabbit a lick. Another sign of Horace's extraordinary individuality was his several allergies which made him sneeze when the wrong kind of dust got in his food. Besides being a delightful tale, *A Hare about the House* is a contribution to the study of animal behavior.

THE RAINBOW BOOK OF NATURE, by Donald Culross Peattie. The World Publishing Company ($4.95). A skilled naturalist-writer presents a series of diverting and instructive observations and comments on various aspects of plant and animal life. He discusses the longevity of ichneumon flies; lobsters and turtles; the growth of molds; the ecology of ponds, meadows, deserts and forests; barnyard life; the antiquity and evolution of domesticated animals; the colors of the insect, bird, fish and flower world; the marvelous adaptations of form and function; the principles of taxonomy; the relation between seasonal changes and animal life; animal parents; ant societies; animal aggressors; plant nomads; the distribution of living things. This is an intelligent, readable book, very well illustrated by Rudolf Freund, and will appeal to anyone 10 years old and up.

IGLOOS, YURTS, AND TOTEM POLES, edited by Friedrich Boer. Pantheon ($3.50). This book, a translation from the German, consists of brief accounts by staff members of the Hamburg Museum of Ethnology and Prehistory of the present life and customs of 13 peoples around the globe. Each narrative is in the first person, as if a child belonging to the tribe or group were describing its ways and experiences to a reader of his own age. A young Australian aborigine tells of the constant search of his Stone Age band for water and food; Aniva, a little Samoan girl, describes the painful ordeal of being tattooed; Abdullah, the Kirghiz boy from Kazakhstan, paints a vivid picture of nomadic life in the vast steppe country between the Caspian Sea and the Altai Mountains in the U.S.S.R.; P'hafôdi, the yellowish-brown–skinned boy from the southwest African bush, recites his adventures as a big-game hunter with bow and arrow. Among others who speak are Kunabi, an Indian boy of the South American Jívaro tribe which hunts with blowpipe and poisoned arrows; Masha, an Ostyak girl of Siberia whose family follows their herd of reindeer on its migratory course; Kul, the Nuer boy from the Sudan; Koshtélen, a Fuegian of the Selk'nam tribe, of whom only 200 are left; Koketl, the Mbowamb boy of central New Guinea; Mbungu, the girl of the Ba-Congo tribe. A book of exceptional merit—lively, well written, full of unusual information. Good illustrations. Ages 9 up.

ALL ABOUT GREAT RIVERS OF THE WORLD, by Anne Terry White. Random House ($1.95). History, science and the story of man's ties with great waterways are very skillfully blended in this book. Miss White writes about the birth of rivers, the famous mysteries of the White and Blue Nile, the effect this twisting and variable stream has had on the course of history, the role of the Amazon, the Yangtze, the Volga and the Mississippi in shaping various lands and the lives of the people along their banks, the natural life of rivers; also about floods, dams, ships, rapids, crocodiles



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A fundamental test of the various theories of beta decay which have been inspired by recent parity experiments is obtained from the quantitative measurement of the spatial asymmetry of the beta particles emitted in the decay of free polarized neutrons.

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and meanders. Now and then Miss White is carried away by her subject and ships a little water, but she has written a top-notch children's book about a fascinating subject.

HERE IS THE FAR NORTH, by Evelyn Stefansson. Charles Scribner's Sons ($3.50). The first part of Mrs. Stefansson's book is an account of a flight she made on the Scandinavian Airlines from Los Angeles to Copenhagen over the Great Circle North Polar route. She comments on the scenery and landmarks along the way and gives details of the history of exploration in these regions. The second part of the story presents brief sketches of Greenland, Iceland and the Soviet sector of the Arctic, describing the land, climate, people and daily life. Mrs. Stefansson is a student of this part of the world and writes easily. Her well-illustrated survey is suitable for adolescents.

ALL ABOUT THE DESERT, by Sam and Beryl Epstein. Random House ($1.95). Dry deserts cover one seventh of the earth's land surface. Except for their scarcity of water they have little else in common. The Sahara is as big as the U. S.; the Painted Desert in Arizona is no bigger than Connecticut. Some deserts are at sea level or below, some are on high plateaus; some are flat, some hilly; some have dunes, some are hard packed with sand, some have flat stone floors. Our Southwest deserts have tall cactuses, but these do not grow in the great Gobi. No camels perambulate the Mojave (although they did in prehistoric times), but they are a regular feature of the Sahara, the Gobi and the Arabian deserts. Ostriches are a familiar sight in Africa's Kalahari but not in South America's Atacama; our deserts have road-runners, but this sturdy little bird is a stranger to other dry places. The Epsteins impart a good deal of sound information about the deserts of the world: what they look like, who first explored them, how they are traveled, why they are dry, what sorts of plants and animals inhabit these regions and how each species handles its water economy. A sound, relaxed primer for children 9 to 12.

EXPLORING WITH YOUR MICROSCOPE, by Julian D. Corrington. McGraw-Hill Book Company, Inc. ($4.95). For those who wish to take up microscopy as an avocation, this thorough, practical manual by the chairman of the zoology department at Miami University in Ohio will serve as a stout guide. It traces the history of the microscope and sketches its general principles, methods of use and different accessories. Various chapters discuss the examination of protozoa, simple algae and infusions, threads and fibers, rocks and minerals, metals and chemicals, bacteria, tissue sections, insects. Good illustrations; bibliographies; information on supply houses. High-school and college age.

THE GOLDEN PICTURE BOOK OF SCIENCE, by Rose Wyler. Simon and Schuster ($1.35). This book is for children of 8 to 10. The topics covered include animals, plants, rocks, gravity, day and night, rain and snow, the sky and the ocean (with 45 experiments) in 50 pages. Implausible as it may seem, this is an instructive little sampler, with good pictures and a genial grab-bag quality.

MONKEY BUSINESS, by Irving Adler. The John Day Company ($2.95). A collection of oddments, mainly hoaxes in the name of science. Among the lot are the New York *Sun* series, which appeared in 1835, purporting to describe Sir John Herschel's discovery of life on the moon; Charles Dawson's Piltdown forgery; Anton Mesmer's career as a medical hypnotist; sundry mountebanks' claims to have made artificial diamonds; and the singular triumph of the learned president of Duquesne University in trisecting the angle with ruler and compass. A diverting hodgepodge.

THE LIFE OF THE BOOK, by Hellmut Lehmann-Haupt. Abelard-Schuman ($3.50). How books are published; the history of printing, illustration, manufacture and design; how books are sold; the joys of book collecting. The author is a well-known specialist in rare books and a bibliographical consultant. His survey is pleasant and knowledgeable but gives remarkably little information, even for a primer, on the anatomy and construction of books or on arts and crafts related to bookmaking.

PAGOO, by Holling Clancy Holling. Houghton Mifflin Company ($3.75). The life story of a hermit crab. This is a sentimental book, too cute for many tastes (*e.g.*, the central character's animal instinct which keeps telling him what and what not to do is called "Old Pal") but it offers a vivid account of life along the seashore and in tide pools—its rhythms, hazards, struggles for survival and rare beauty. There are marginal drawings and full-color plates by the author and his wife.

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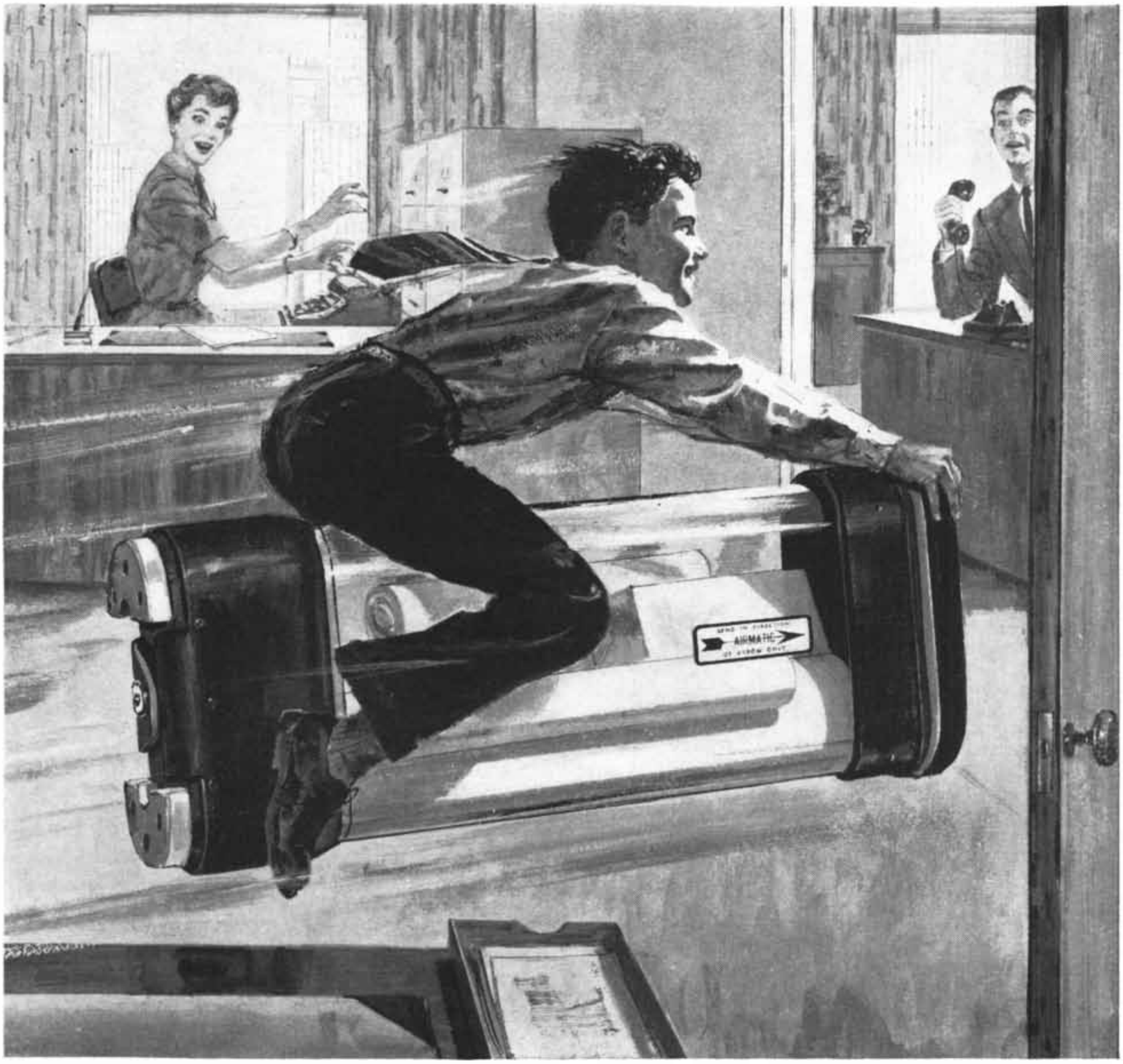

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ANNUAL INDEX

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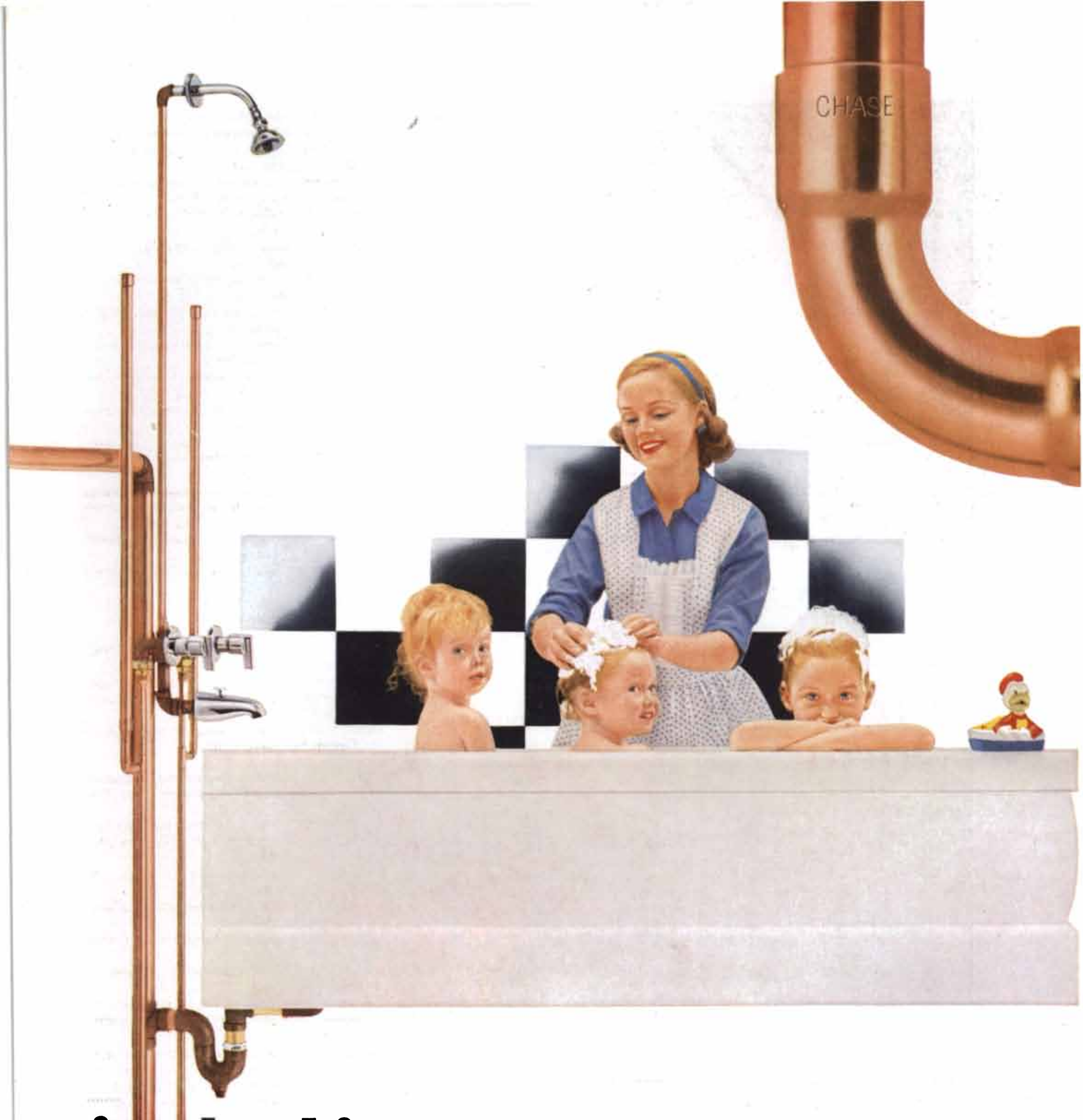

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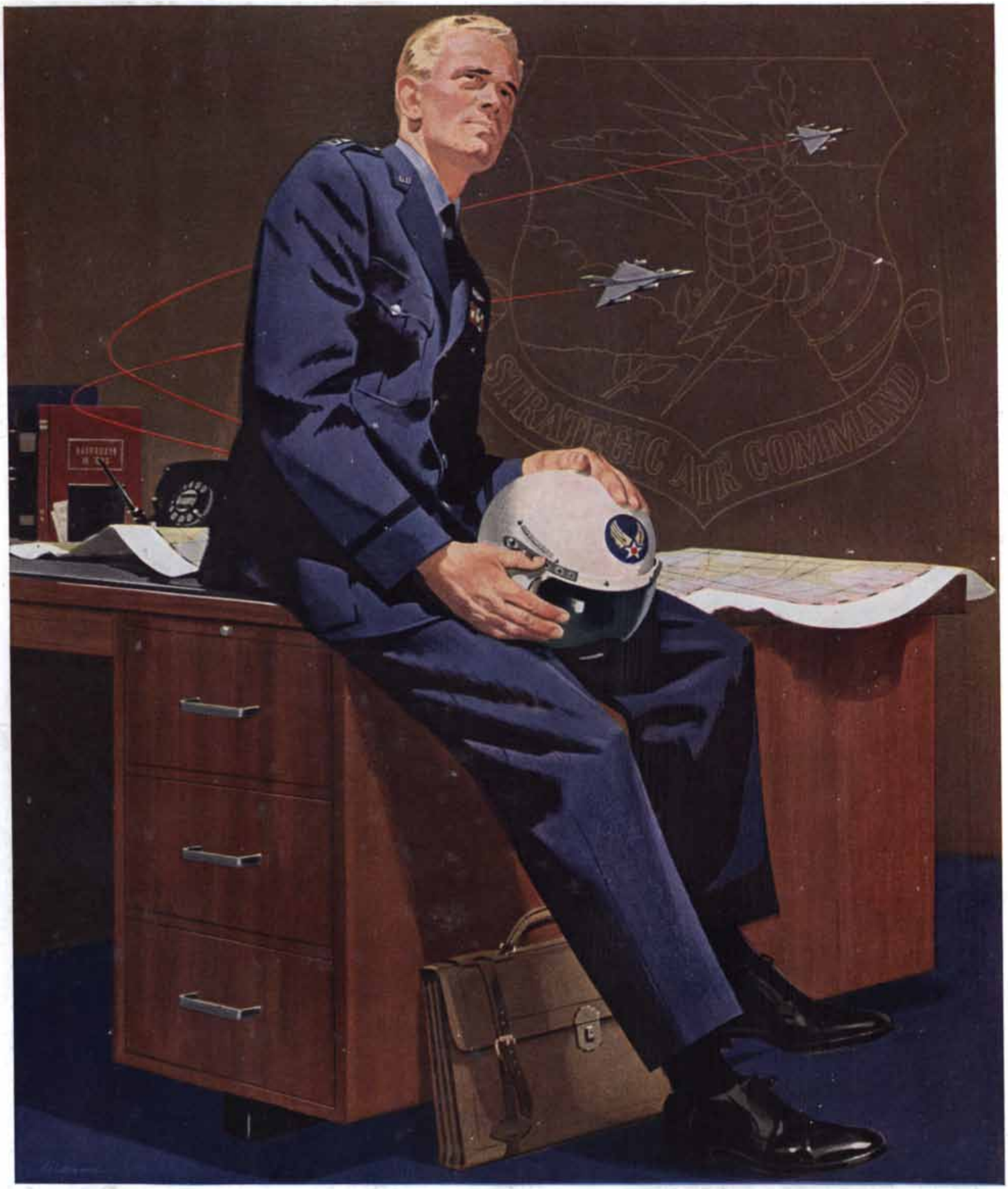
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